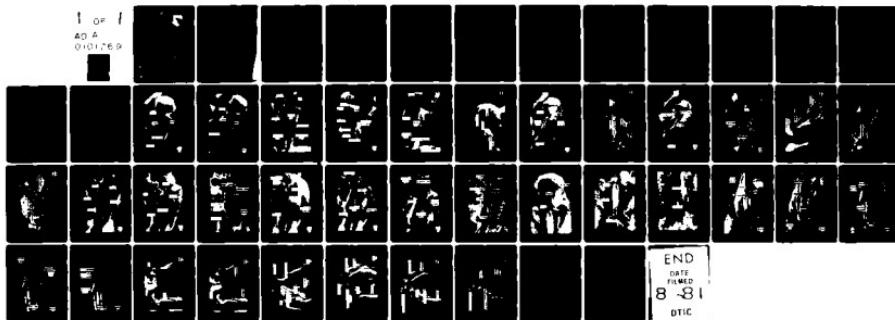


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A COMPARATIVE SURVEY OF SELECTED MUSCLES OF THE TRUNK IN FOUR SPECIES OF PRIMATES

JOSEPH R. VORRO, PhD

ROBERT WM. LITTLE, PhD

MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN 48824

ARNOLD R. SLONIM, PhD

AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY

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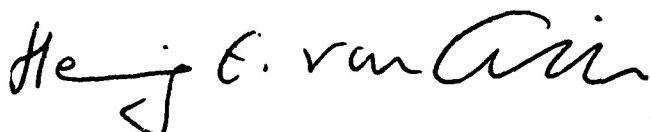
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The experiments reported herein were conducted according to the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



HENNING E. VON GIERKE
Director
Biodynamics and Bioengineering Division
Air Force Aerospace Medical Research Laboratory

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SUMMARY

A comparative survey was made of selected muscles in the back of a rhesus, baboon, chimpanzee and man, using embalmed specimens. Musculature features were identified, and similarities and differences between the four primates were noted. Differences in these muscles between primates might explain differences in the mechanical properties of spinal ligaments or in the spinal system responses. The specimens were dissected and photographs were taken of each exposed muscle layer in the back. These photographs were used to make comparisons of position, relationship and attachment. Information on the similarities and differences of the major muscles supporting the spinal system will assist interspecies scaling and model development for use in evaluating human injuries.

Major adaptive locomotor differences were paralleled by numerous differences in musculature. The rhesus and baboon are classified as quadrupeds, the chimpanzee as a brachiator and the human as bipedal. With the exception of the splenius muscle, the anatomical variation was greater in the superficial musculature than in the deeper paraspinal muscles. The human specimen shared certain superficial muscular characteristics with each of the other two locomotor groups; however, all four species had very similar deep paraspinal musculature.

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PREFACE

This study was conducted in the Department of Biomechanics, College of Osteopathic Medicine, Michigan State University, East Lansing, Michigan 48824, under AF Contract No. F33615-79-C-0514. Dr. Robert William Little, Professor and Chairman of the Department, was the Principal Investigator; Dr. Robert P. Hubbard was the Co-investigator. Dr. Joseph R. Vorro, Assistant Professor in the Department of Anatomy, was in charge of the muscle study phase of this project and the senior author of this report. The experiments, which cover the first year and a half of a three-year effort, were conducted in support of Work Unit 72311409, "Mechanical Stress on Soft Tissue Material Properties." Dr. Arnold R. Slonim, Biodynamic Effects Branch, Biodynamics and Bioengineering Division, Air Force Aerospace Medical Research Laboratory, was the project scientist and contract monitor.

The authors gratefully acknowledge the valuable assistance of Mrs. Arvilla M. Bolley for her help in typing this report. The cooperation and assistance of Lt. Col. A.R. Banknieder and his staff of the Veterinary Sciences Division, Air Force Aerospace Medical Research Laboratory, and of Dr. Frederick Coulston and Dr. Charles E. Graham, Director and Deputy Director, respectively, International Center of Environmental Safety of Albany Medical College, Holloman AFB, New Mexico, in providing primate cadaveric specimens vital to this study are very much appreciated.

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INTRODUCTION

Major adaptive locomotor differences in monkeys and apes are paralleled by numerous quantitative differences in their musculature. These structural differences are of obvious importance where subhuman primates are used as surrogates in human injury research. Knowledge of the anatomical, physiological and biomechanical properties of the major muscles supporting the spine will aid in an understanding of the mechanisms by which injuries occur in aircraft mishaps and, through interspecies scaling and modeling, the development of countermeasures to safeguard the aircrrewman.

Although anatomical studies have been conducted on each of the species in this survey, these studies, for the most part, have not been of a comparative nature, rather they have been made of isolated species. In these cases, direct comparison is difficult since these studies do not have corresponding observations or methods. Additionally, most of the previous studies do not include observations on the deep musculature of the back.

The present study was undertaken to acquire comparative information regarding the back musculature of individual specimens of subhuman primates: rhesus, baboon, chimpanzee, and one human. The muscles studied were panniculus carnosus, trapezius, latissimus dorsi, deltoid, teres major and serratus anterior. In addition, this survey highlights salient morphological features of the deep back musculature (splenius, rhomboides, serratus posterior superior, atlantoscapularis, erector spinae, transversospinalis, and the intervertebral muscular system) and the major similarities and differences of the four species.

METHODS

A comparative survey was made of selected muscles in the back of a rhesus, baboon, chimpanzee, and human. Each specimen was treated with standard embalming techniques and injected with a solution of formalin, alcohol, glycerin and phenol. After fixation, the specimens were wrapped in terry cloth, moistened with a mild embalming solution and stored in plastic airtight containers.

Thirteen muscles and muscle groups were chosen for study: 1. panniculus carnosus, 2. trapezius, 3. latissimus dorsi, 4. deltoid, 5. teres major, 6. serratus anterior, 7. splenius, 8. rhomboides, 9. serratus posterior superior, 10. atlantoscapularis, 11. erector spinae, 12. transversospinalis, and 13. the intervertebral muscular system. The muscles could be separated conveniently into two categories: 1, superficial musculature (muscles 1-6), chosen because they provide orientations, relationships and a basis of comparison between species; and category 2, deep musculature (muscles 7-13), chosen because they attach directly to the vertebral column. The superficial musculature includes the prominent muscles of the back; however, this survey does not include all superficial back musculature. The survey of the deep back muscles includes all of the muscles encountered on the caudal aspect of the vertebral column.

The survey includes a series of black and white photographs and a written description of the musculature. In the photographs, muscles are labeled and two vertebral levels (7th cervical vertebra and 12th thoracic vertebra) are indicated for reference and comparison of relationships. The description of the musculature includes a general overview for each muscle: position, relationships and attachments. Specimen differences or similarities are noted where applicable.

SURVEY

1. MUSCLE (M.) PANNICULUS CARNOSUS

General Description - A skeletal muscle layer found distributed within the superficial fat (this fat layer is occasionally referred to as the panniculus adiposus and is synonymous with subcutaneous tissue or subcutaneous fat). The degree of development of the panniculus carnosus varies widely. It is most commonly present in domestic quadrupeds such as sheep and horses where it forms a sheet present over most of the body wall. The essential feature of the panniculus carnosus is that one end of each muscle fiber is attached to the skin and the other end is usually attached to deep fascia (connective tissue) or bone. The panniculus carnosus will not be found on any of the specimens as whatever portions may be present are removed while reflecting and removing the skin.

Specimen Differences

Rhesus - Both caudal and thoracic portions vary in extent. The panniculus carnosus arises from the superficial fascia overlying the anterior surface of the thigh and gluteal regions and from the lumbar fascia lateral to the midline. Fibers converge in or near the axilla and insert via a tendon onto the humerus bone near to the insertion of the pectoralis major muscle.

Baboon - The panniculus carnosus overlies and even coexists with the latissimus dorsi muscle. It is variously developed throughout its extent in the baboon. Fibers converge and insert into the humerus in a manner similar to the rhesus.

Chimpanzee and Human - The panniculus carnosus is difficult to demonstrate and describe in these species. It may be found in varying degrees in scalp, face, scrotal and nipple areas. Where present in humans, the panniculus carnosus is called the platysma muscle and is found covering the anterior superior portion of the chest to the areas around the anterior portion of the neck superiorly to the lower lip.

2. M. TRAPEZIUS

General Description - A trapezoidal shaped muscle is superficially situated in the upper back and posterior region of the neck. It is relatively thin and flat. Fibers originate in occipital, cervical and thoracic regions and pass distally toward the bones of the shoulder. Occipital and upper cervical

fibers insert into the posterior lateral portion of the clavicle bone. Lower cervical and upper thoracic fibers reach the acromion process (tip) of the scapula. Lower thoracic fibers converge generally to the scapula spine. This muscle is readily seen in all specimens in situ and reflected.

Specimen Differences

The trapezius muscle in all four specimens originates on the posterior surface of the occipital bone (for the cranial limit of the muscle). The thoracic limit for the muscle origin varies for the specimens: rhesus and baboon - between thoracic levels 9 and 10, chimpanzee and human - between thoracic levels 11 and 12. All muscles insert similarly on the acromion and spine of the scapula.

3. M. LATISSIMUS DORSI

General Description

- The latissimus dorsi muscle is broad and triangular and is situated superficially in the middle to lower part of the back immediately inferior to the trapezius muscle. It arises by tendinous fibers from the spines and supraspinous ligaments of the lower thoracic vertebrae and the thoracolumbar fascia. The fibers course superiorly and anterolaterally becoming fleshy or muscular a few centimeters from their origins. The muscle converges toward the posterior axillary wall finally attaching via a tendon onto the anterior surface of the humerus bone. The latissimus dorsi is readily seen in each of the specimens.

Specimen Differences

The superior limit of the latissimus dorsi occurs between thoracic levels 5 and 6 in our specimens. The superior portions of the latissimus in the rhesus and baboon specimens converge as a tendon to join the tendon of the teres major muscle. The remaining larger portions of the muscle form a tendon that inserts individually on the humerus. The chimpanzee and human specimens have but a single band-like tendon that insert upon the humerus.

4. M. DELTOID

General Description

- The deltoid muscle is a thick triangular muscle that caps the tip of the shoulder. It is comprised of three divisions (anterior, middle and posterior) that arise respectively from the lateral portion of the clavicle, from the lateral aspect of the acromion (tip of the shoulder), and from the spine of the scapula.

The entire muscle inserts onto the lateral surface of the humerus near to its midpoint.

Specimen Differences

The origin of this muscle was very consistent for our specimens. The humeral insertion of the muscle is more distally placed in the chimpanzee and human than is the case for the rhesus and baboon.

5. M. TERES MAJOR

General Description - The teres major is a thick rounded muscle that takes origin from the posterior surface of the inferior angle of the scapula. The fibers pass laterally to the anterior proximal portion of the humerus where they insert via a tendon.

Specimen Differences

The amount of fibers of the teres major exposed after reflection of the skin depended upon the size and shape of the trapezius and latissimus dorsi muscles. The teres is found sandwiched between these two muscles. More of the teres is readily seen in the chimpanzee and human than in the remaining specimens. No noteworthy variations were observed in origin, insertion or path of fiber bundles.

6. M. SERRATUS ANTERIOR

General Description - The serratus anterior is a thin, muscular sheet overlying the lateral portion of the thoracic cage. It originates by slips or separate digitations from either cervical or thoracic areas and inserts along the entire length of the vertebral border of the scapula.

Specimen Differences

Rhesus - This animal has both cervical and thoracic portions of the serratus anterior. The two portions are continuous; however, the cervical portion begins with separate digitations from the transverse processes of the last five cervical vertebrae, while the thoracic portion arises from the caudal portions of the first nine ribs a few centimeters dorsal to the beginning of the costal cartilages. Both sets of fibers insert along the vertebral border of the scapula.

Baboon, Chimpanzee, Human -

These specimens all lack a cervical portion of the serratus anterior muscle. In the baboon specimen,

the origin extends from rib 5 to rib 9, for the chimpanzee specimen from rib 3 to rib 11 and in the human from rib 1 to rib 8. The insertion is essentially similar to the rhesus, that is, along the entire vertebral border of the scapula.

7. M. SPLENIUS

General Description - The splenius is a thick, flat muscle running obliquely across the back of the neck, covering and holding the deeper muscles in place. It is located immediately beneath the trapezius and arises from spinous processes of cervical and thoracic vertebrae and the ligamentum nuchae. The muscle inserts along the posterior aspect of the occipital bone in the area behind the vertebrae.

Specimen Differences

In the human specimen, the splenius is divided into two portions: the superior portion being called the splenius capitis and a more inferior continuation called the splenius cervicis. The other specimens, the rhesus, chimpanzee and baboon, had a similar capitis portion but lacked the cervical component.

8. M. RHOMBOIDES

General Description - The rhomboides muscles are flat and sheet-like arising from the nuchal area of the occipital bone inferiorly to the spines of the thoracic vertebrae. Fibers are directed downward and lateralward to insert on the medial borders of the scapulae below the spines.

Specimen Differences

Rhesus - The rhomboides muscle in the rhesus is composed of three portions each easily separable from the other. The superior most portion (pars capitis) is slender and arises from the medial aspect of the superior nuchal line of the occipital bone. The middle portion (pars cervicis), wider than pars capitis, arises from the ligamentum nuchae. The inferior most portion of the rhomboides (pars dorsi) arises from the vertebral spines to a level inclusive of the upper thoracic vertebrae. All portions insert directly onto the medial border of the scapula.

Baboon - Superior most fibers arise from the occipital bone deep to the origin of the trapezius muscle. The remainder of the muscle takes origin from the ligamentum nuchae and thoracic vertebrae to include thoracic level 6. All fibers insert directly onto the medial border of the scapula.

Chimpanzee - The rhomboides muscle in this specimen is a single individual sheet taking an origin extending from lower cervical and upper thoracic vertebrae to T6. The muscle attaches along the medial border of the scapula.

Human - The rhomboides muscle in the human specimen is composed of two separate portions (rhomboides major and rhomboides minor). The origin is similar in extent to the chimpanzee and the fibers attach along the medial scapula border.

9. M. SERRATUS POSTERIOR SUPERIOR

General Description - The serratus posterior superior lies underneath the rhomboid layer and immediately superficial to the intrinsic back muscles. This muscle extends from the ligamentum nuchae and the spines of the last cervical and several upper thoracic vertebrae laterally to the caudal borders of the second to fifth ribs.

Specimen Differences

No noteworthy variations were observed.

10. M. ATLANTOSCAPULARIS

General Description - This muscle originates from the dorsal surface of the transverse process of the atlas (first cervical vertebra). It appears as a thin ribbon of muscle just beneath the trapezius muscle and inserts upon the scapula.

Specimen Differences

This muscle is present only in the rhesus and baboon. A somewhat homologous structure is found in the chimpanzee and human. In the latter cases the muscle is called the levator scapulae muscle.

11. M. ERECTOR SPINAE (SUPERFICIAL LONGITUDINAL MUSCLES OF THE BACK)

General Description - The erector spinae muscle group begins in the sacral region, from the ilium and associated ligaments. As it ascends along the lumbar spines it thickens from additional slips of muscle contributed at these levels. At approximately the last rib, the erector spinae divides into three columns that ascend the back of the chest. The individual muscles making up the three columns insert variously into adjoining ribs and vertebrae. The three columns of the erector spinae include the following individually named

muscles:

1. Medial column: lies along vertebral spines from upper lumbar to cervical levels.
 - A. spinalis thoracic
 - B. spinalis cervicis
 - C. spinalis capitis
2. Intermediate column: comprises the bulk of the erector spinae.
 - A. longissimus thoracis
 - B. longissimus cervicis
 - C. longissimus capitis
3. Lateral column: consists of an ascending series of slips attached successively between the angles of the ribs and transverse processes of the lower cervical vertebrae.
 - A. iliocostalis lumborum
 - B. iliocostalis thoracis
 - C. iliocostalis cervicis

Specimen Differences

Rhesus - The erector spinae group is divisible into a lateral column consisting of individual iliocostalis muscles and a more medial column, the longissimus muscles. A medial accumulation of muscles, called the spinalis muscles, is modified and different in the rhesus. The origin of the spinalis is spread laterally over the deeper musculature. Lumbar, dorsal and cervical portions may be identified, although the cervical portion is variable.

Baboon, Chimpanzee, Human -

The erector spinae group for these specimens is very similar to the explanation given in the general description. The cervical portion of the iliocostalis is absent in the baboon and chimpanzee, but present in the human.

12. M. TRANSVERSOSPINALIS (DEEP LONGITUDINAL MUSCLES OF THE BACK)

General Description - This muscle group is found immediately deep to the erector spinae group. The muscles consist of a large number of individual members that run obliquely cranially and medially, from transverse processes to vertebral spines. The individual muscles making up this group are generally given the following designations:

1. Semispinalis thoracis: extends from transverse processes of lower thoracic vertebrae to spinous processes of upper thoracic and lower cervical vertebrae.

2. Semispinalis cervicis: underlies the semispinalis thoracic; this portion runs from transverse processes of upper thoracic vertebrae and inserts into the spines of cervical vertebrae.
3. Semispinalis capitis: underlies the splenius capitis and runs from the transverse processes of upper thoracic and lower cervical vertebrae; it is inserted into the area between the superior and inferior nuchal lines of the occipital bone.
4. Multifidus: consists of short, triangular-shaped bundles lying just deep to the semispinales. The bundles generally originate from transverse processes of thoracic and cervical vertebrae, traverse a number of vertebrae (2 to 5) while ascending to insert on vertebral spinous processes.

Specimen Differences

No noteworthy variations were observed.

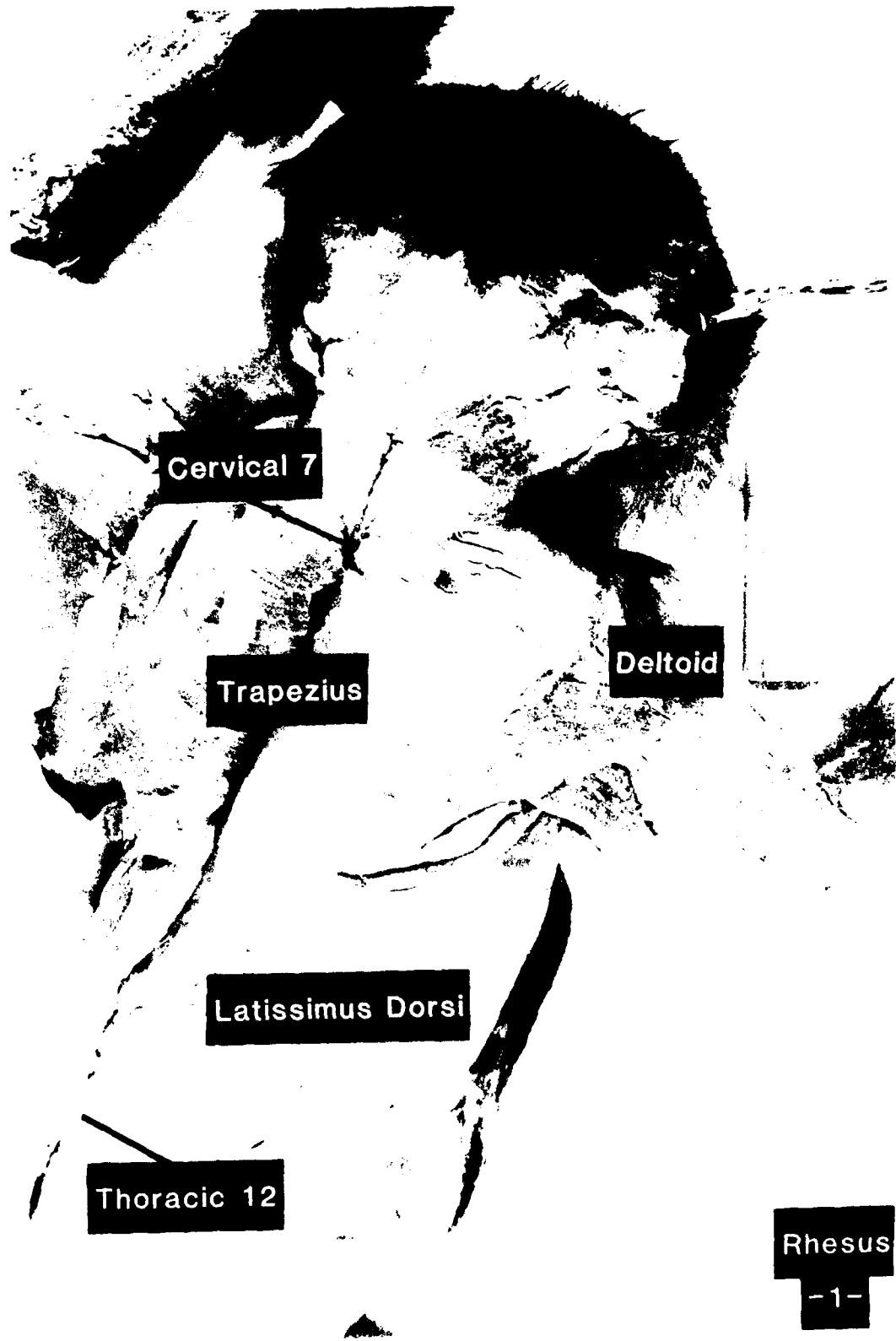
13. INTERVERTEBRAL MUSCULAR SYSTEM

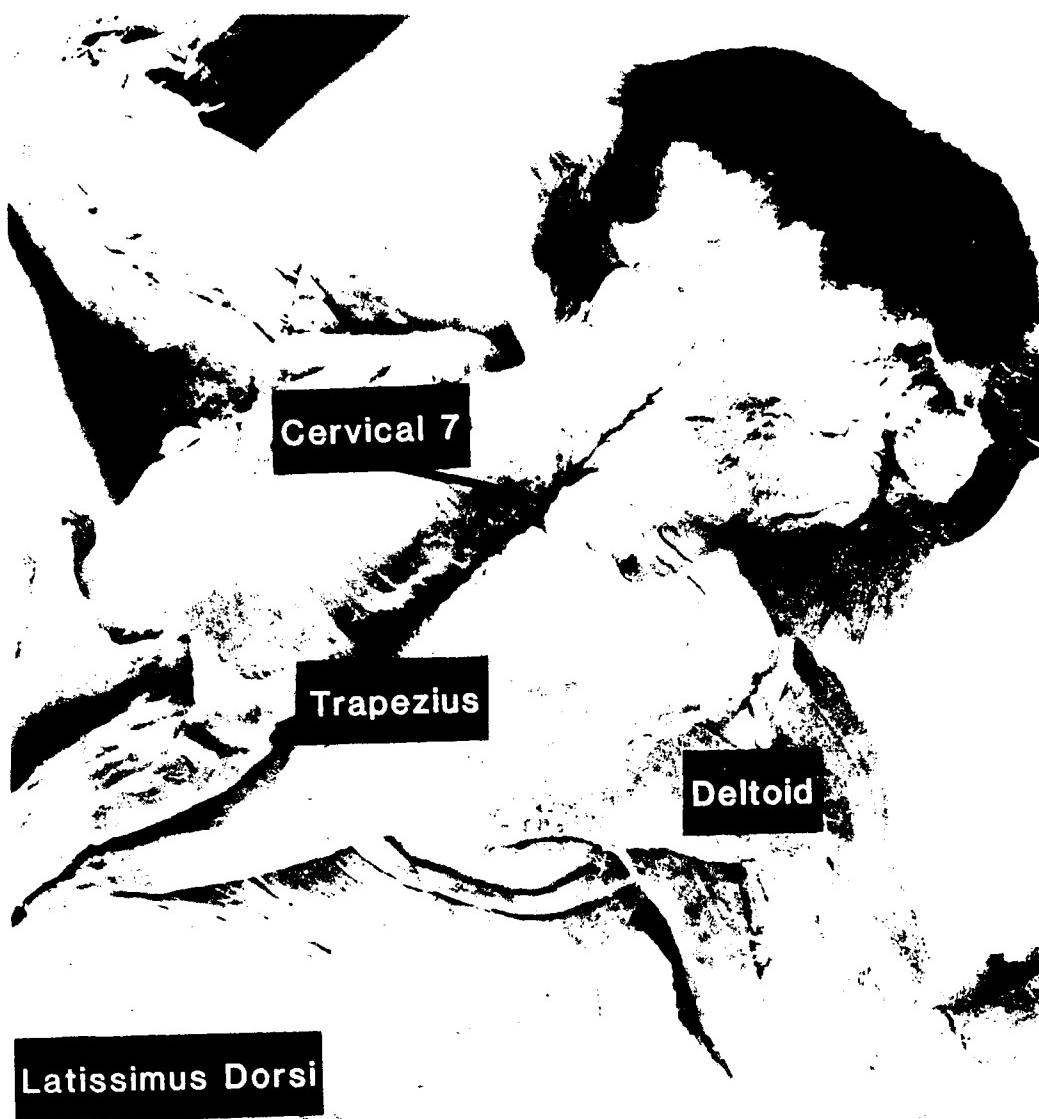
General Description - These muscles are generally absent or poorly developed in the thoracic region, but found more consistently and better developed in the cervical and lumbar regions.

1. Interspinales: consist of muscular slips lying alongside the interspinous ligaments; these slips connect adjacent spines.
2. Intertransversarii: are muscular slips that extend between adjacent transverse processes.

Specimen Differences

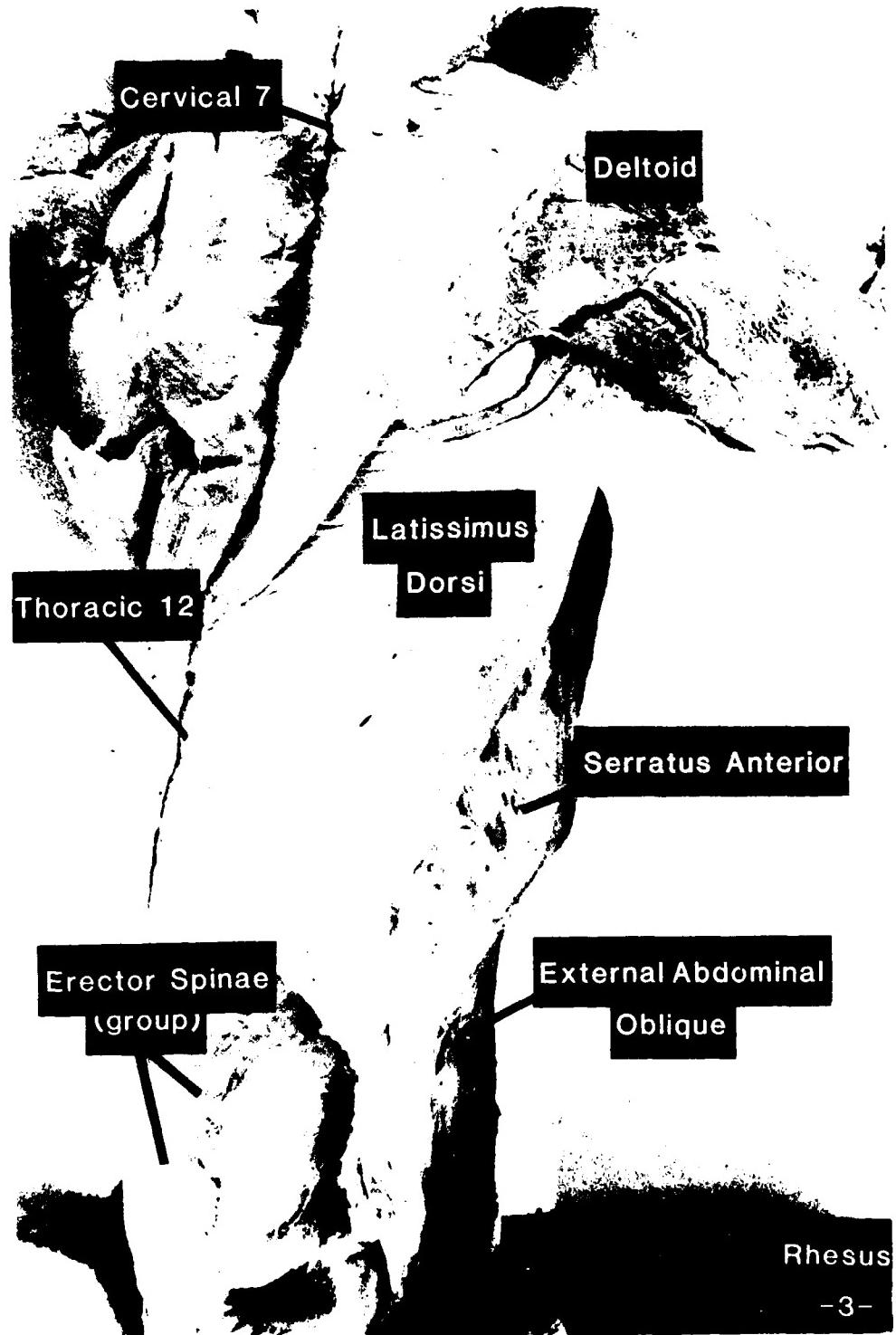
No noteworthy variations were observed.



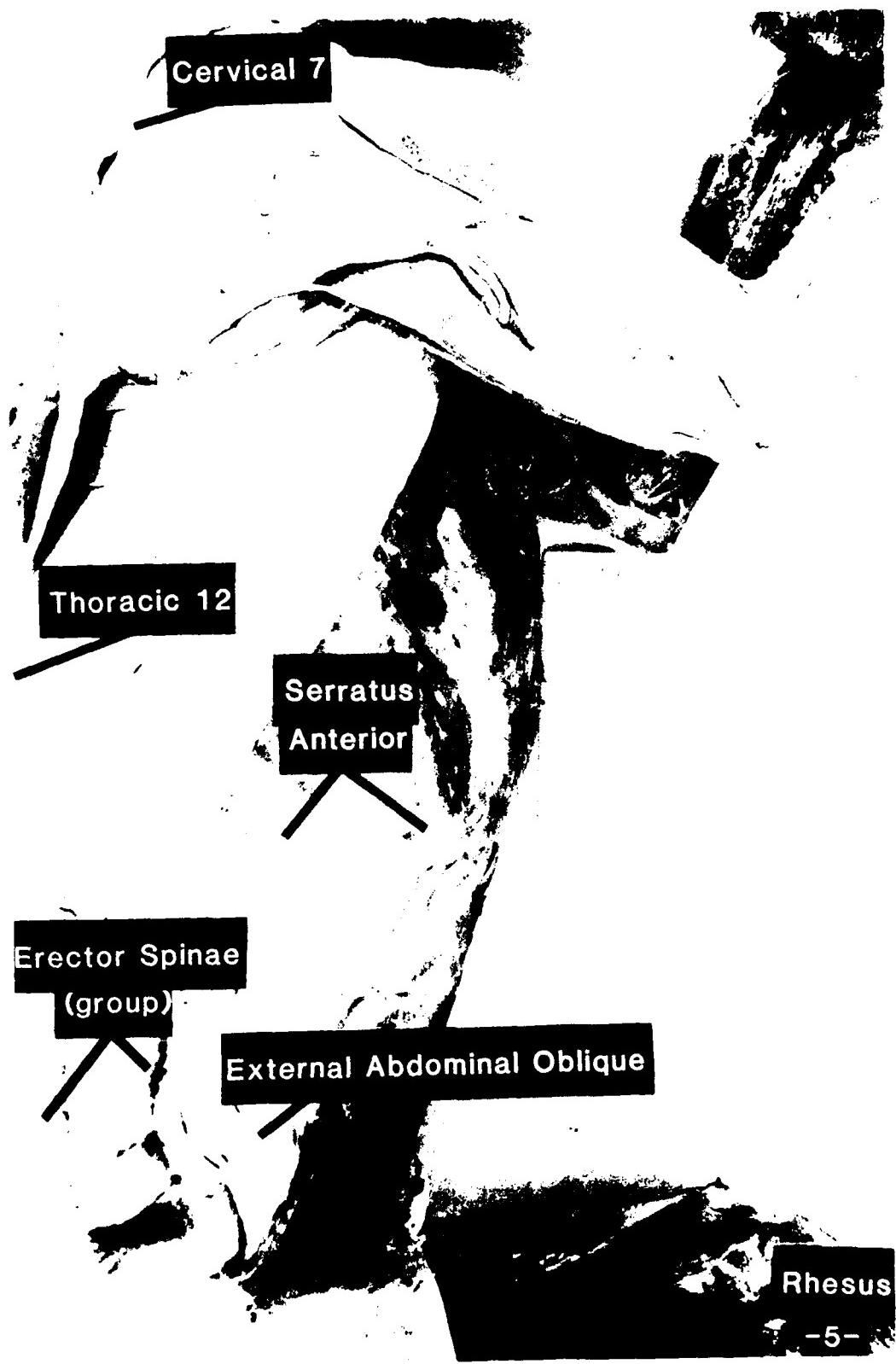


Rhesus

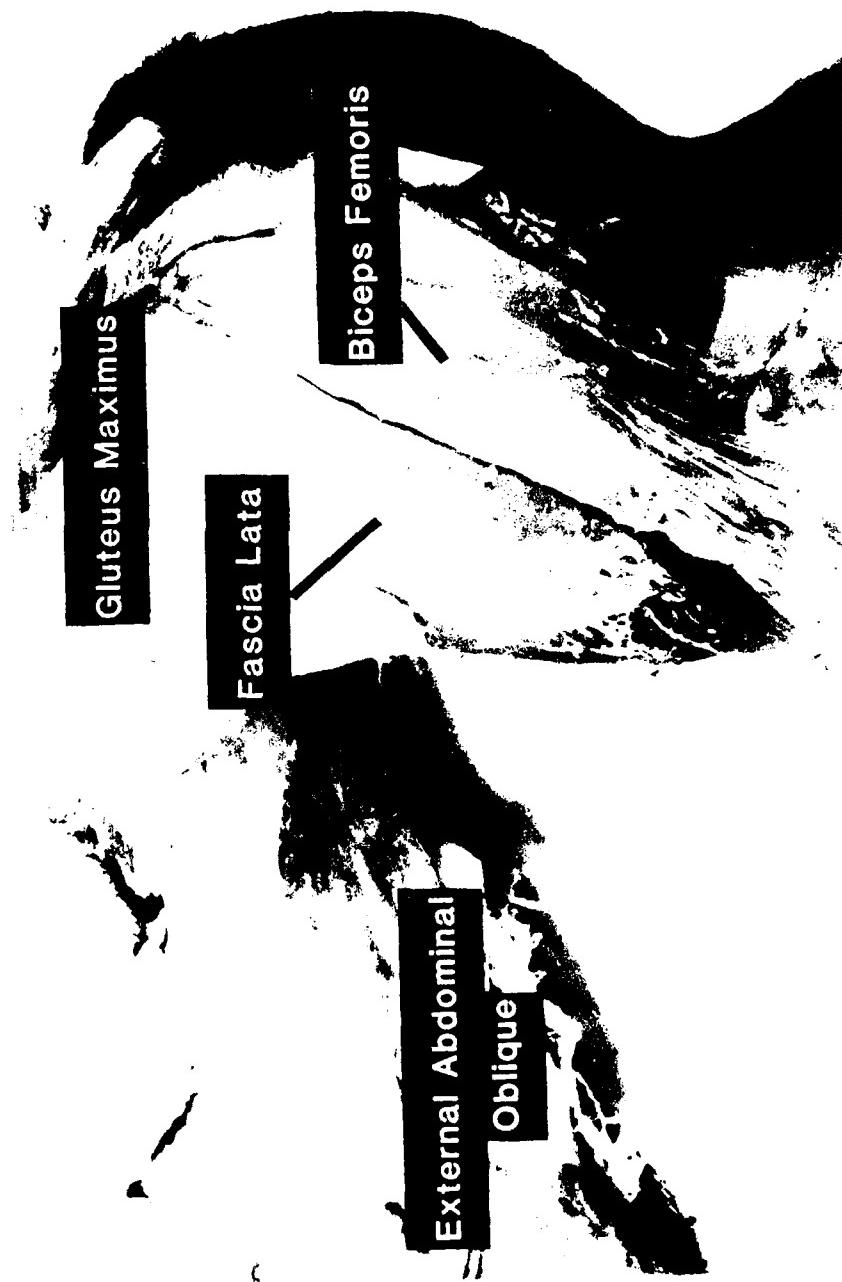
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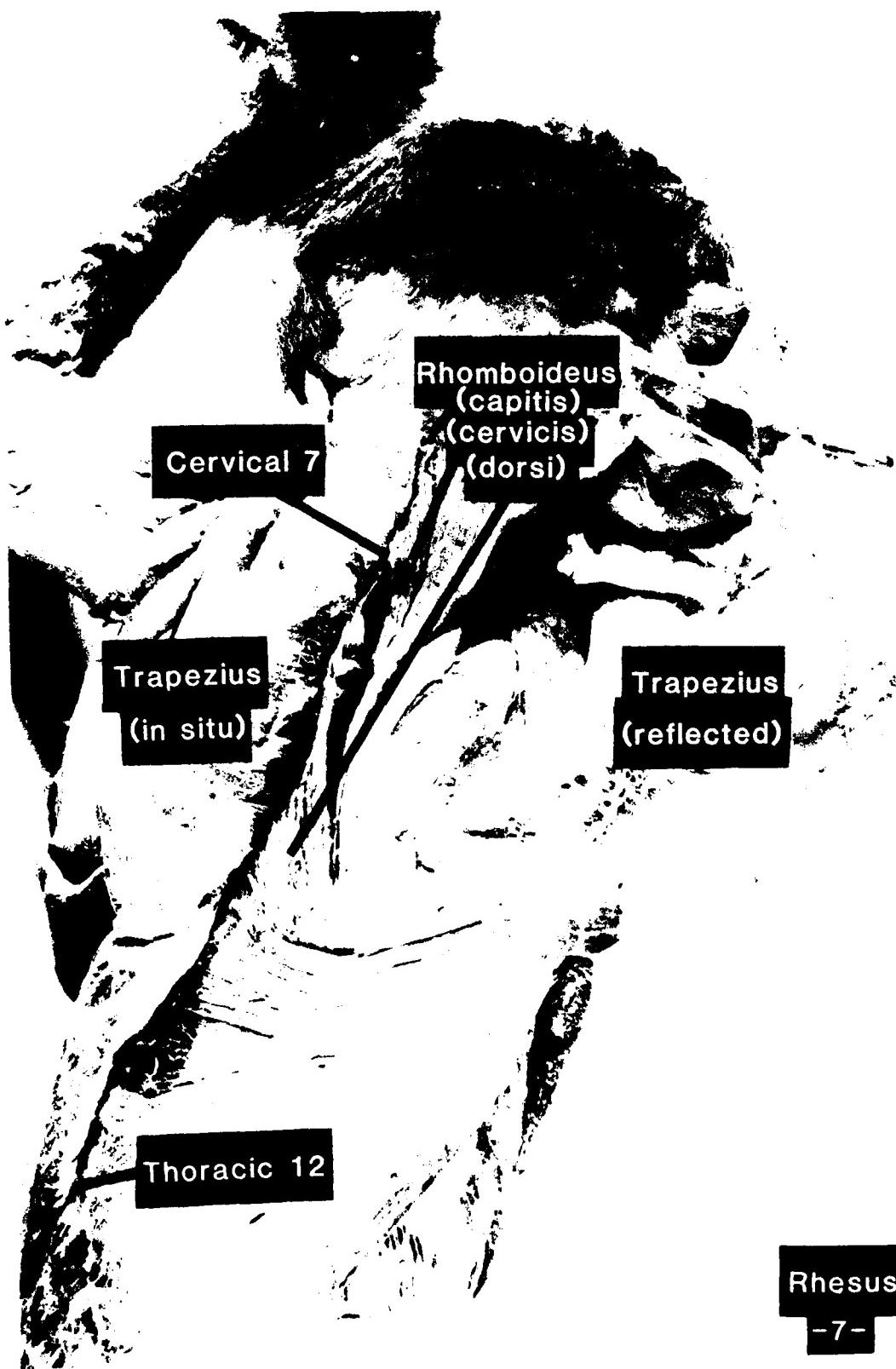






Rhesus
-6-



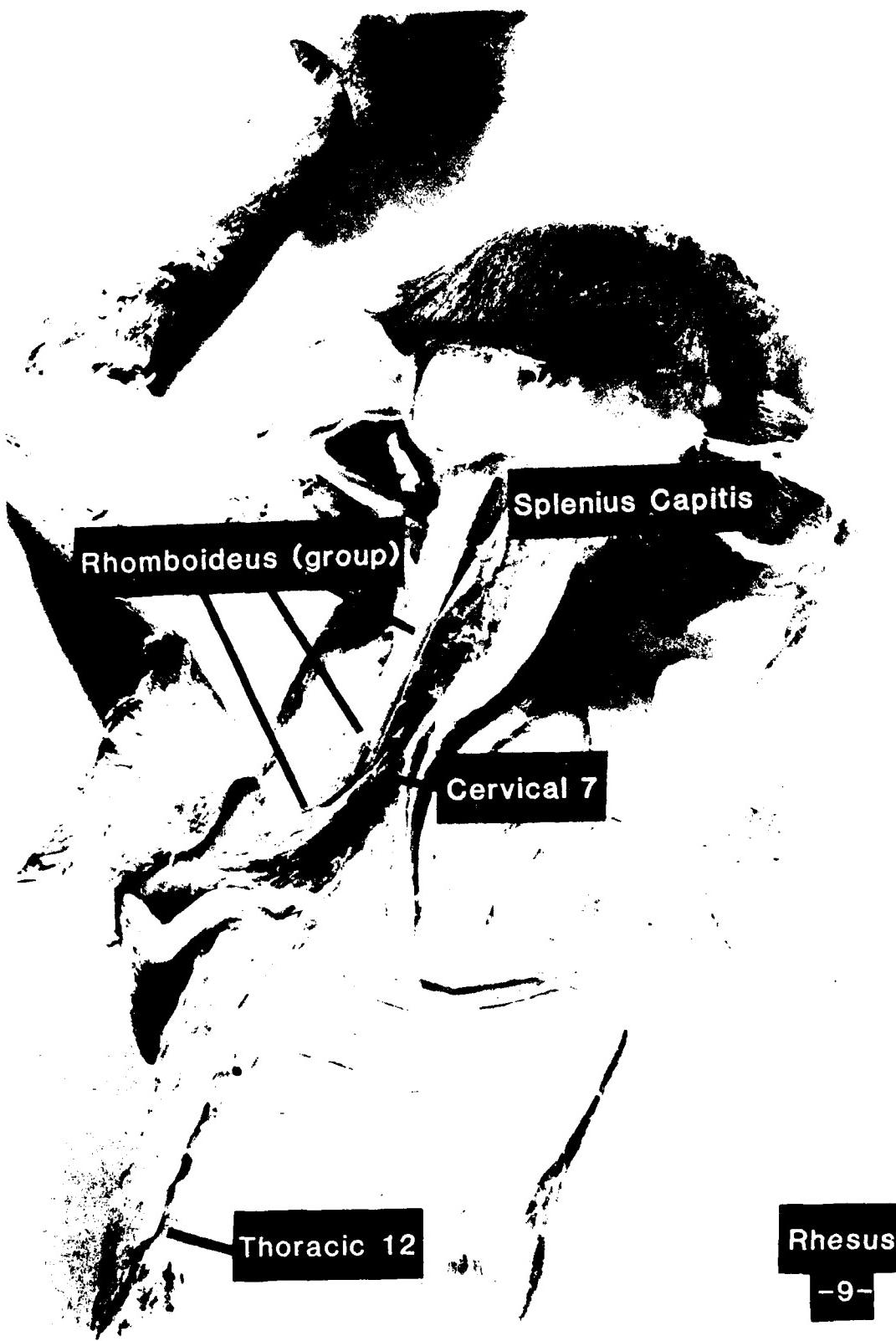


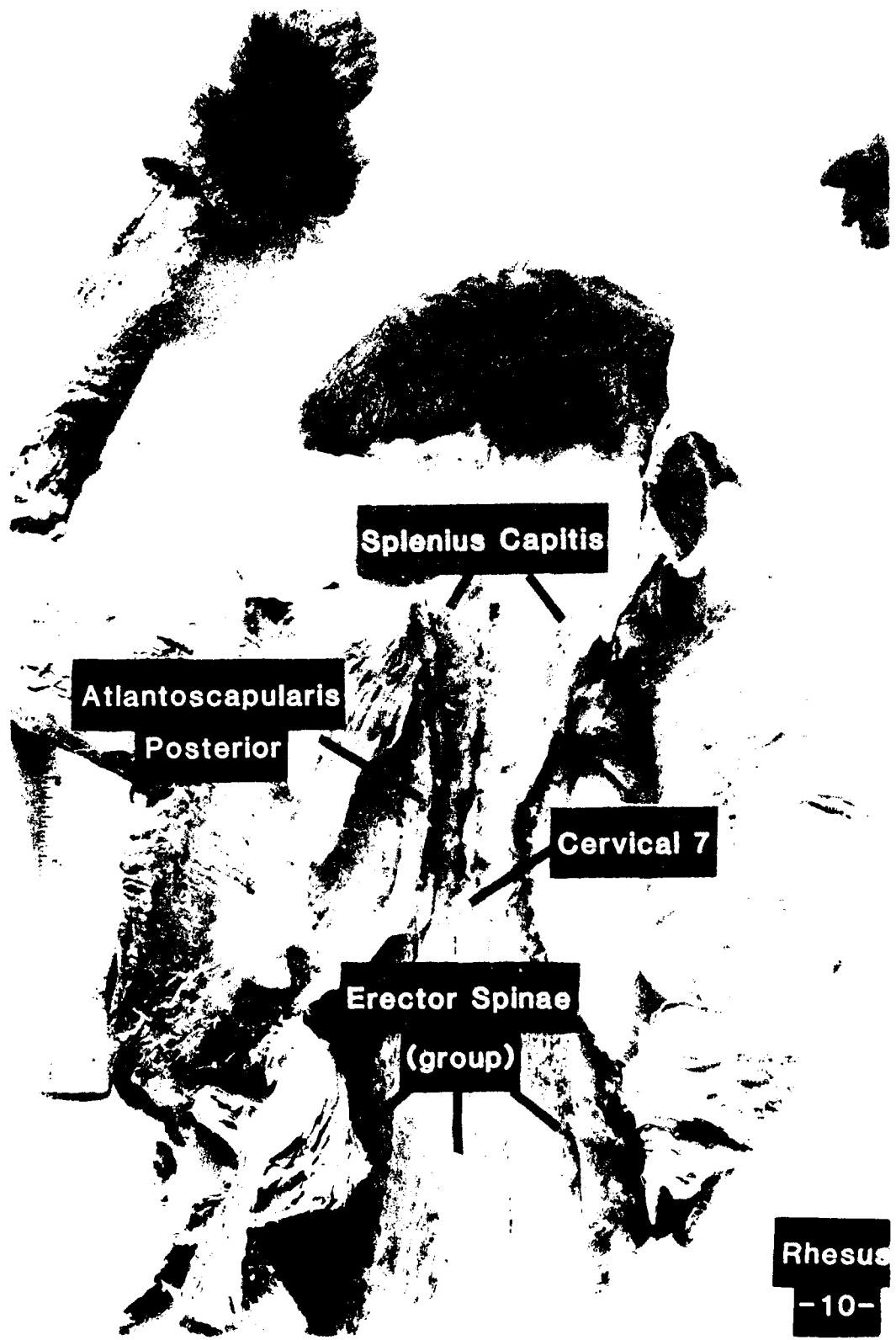
Rhesus
-8-

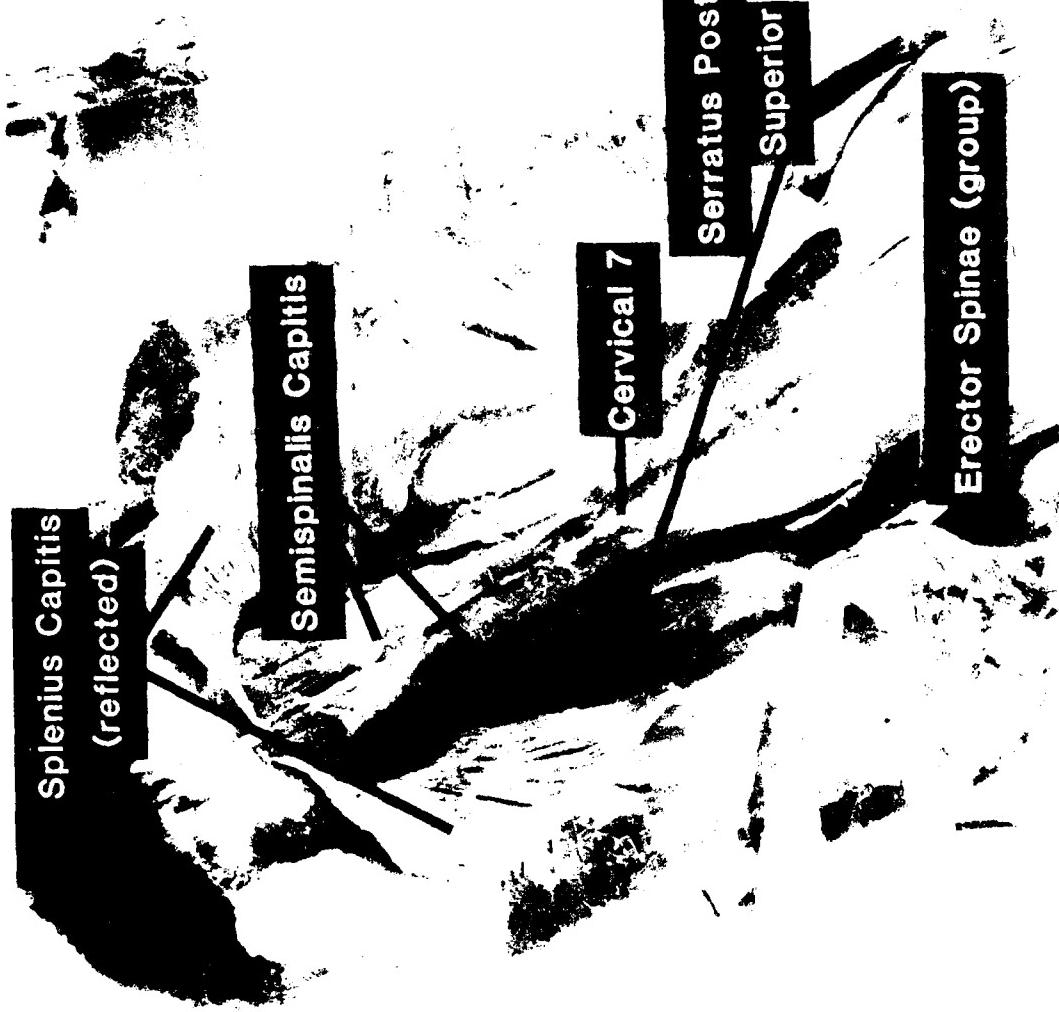
Latissimus
Dorsi

Rhomboideus
(capitis) (cervicis) (dorsi)

Cervical 7







Rhesus

-11-







Rhesus

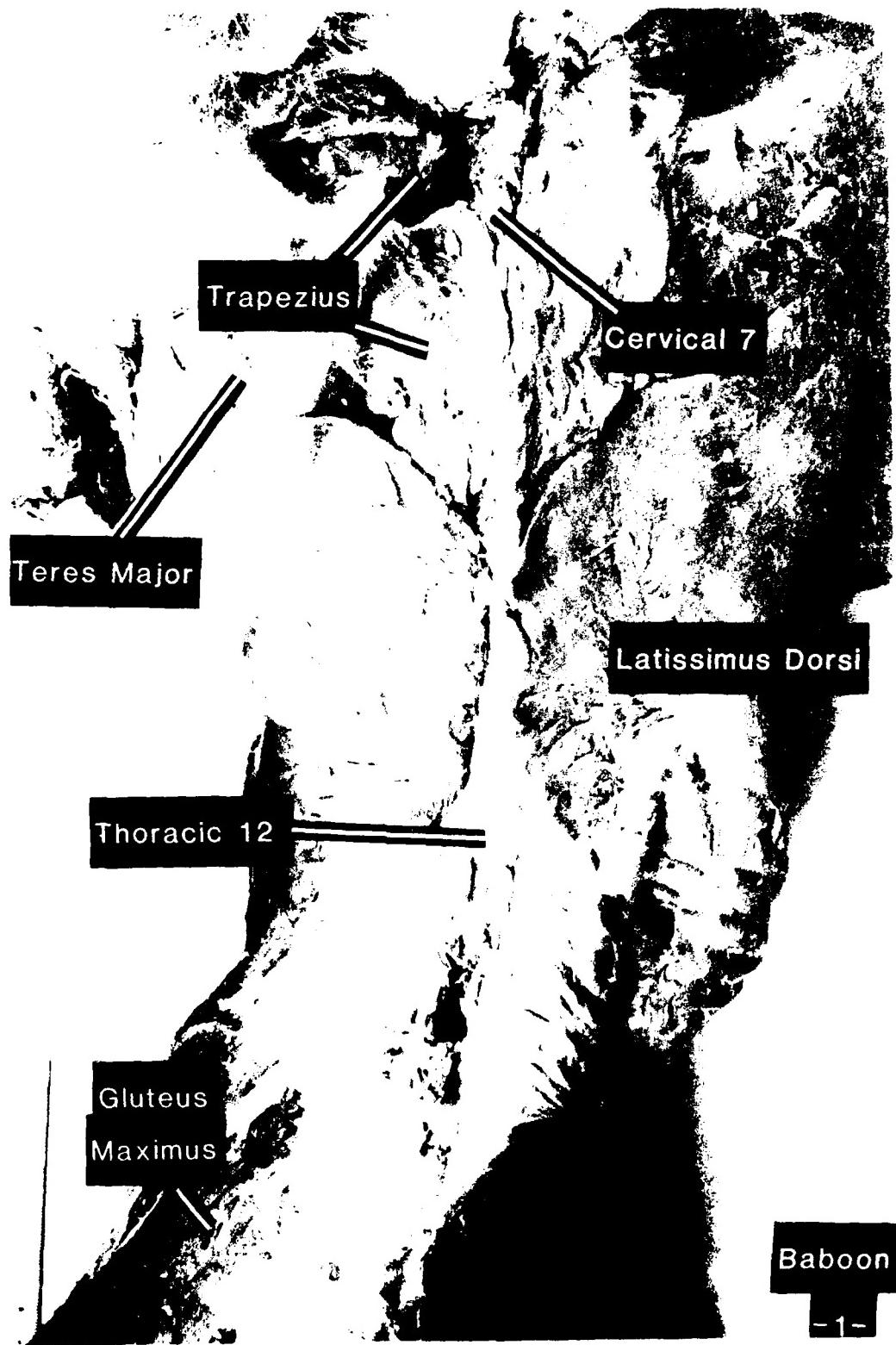
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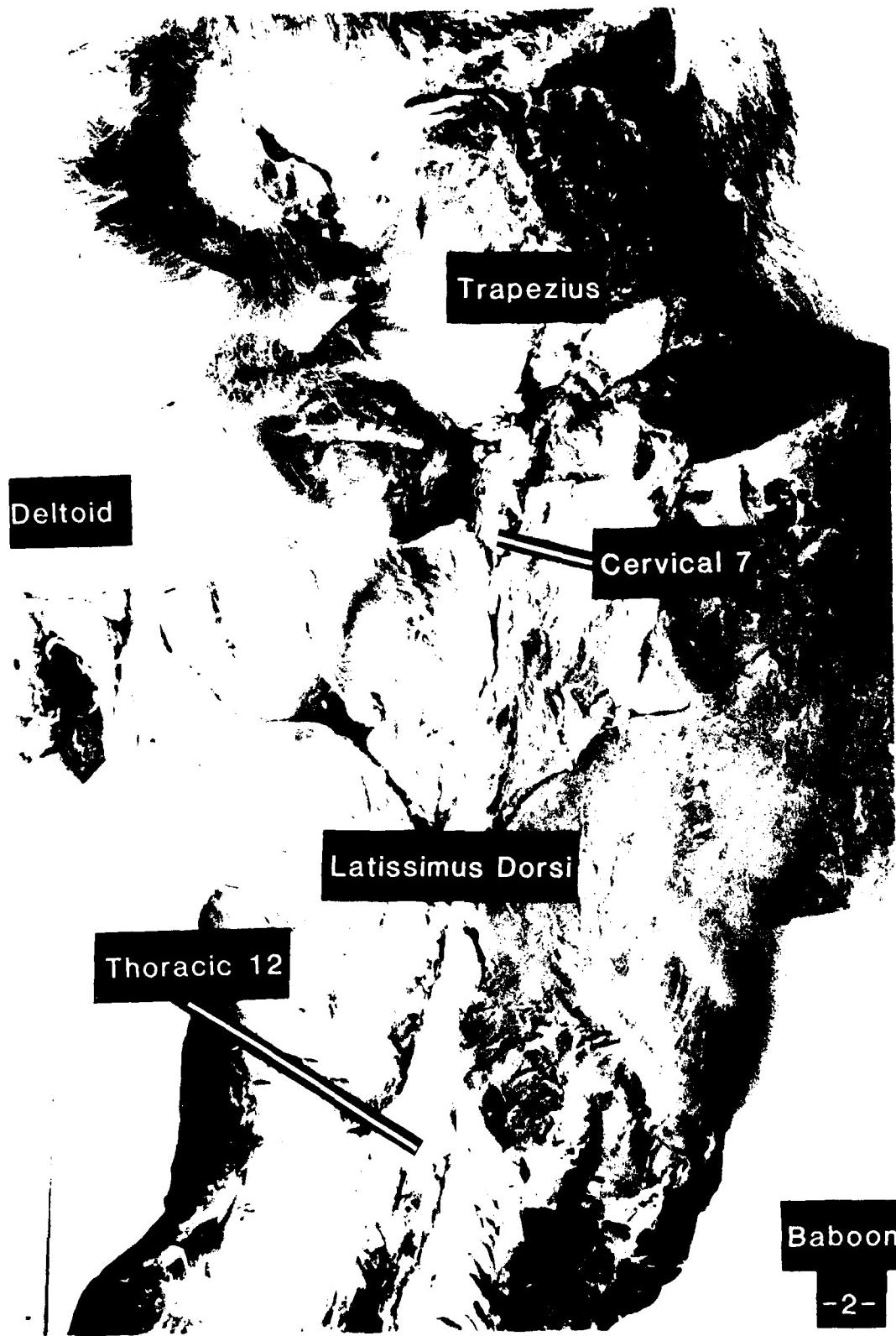
Cervical Vertebral Spinous
Processes

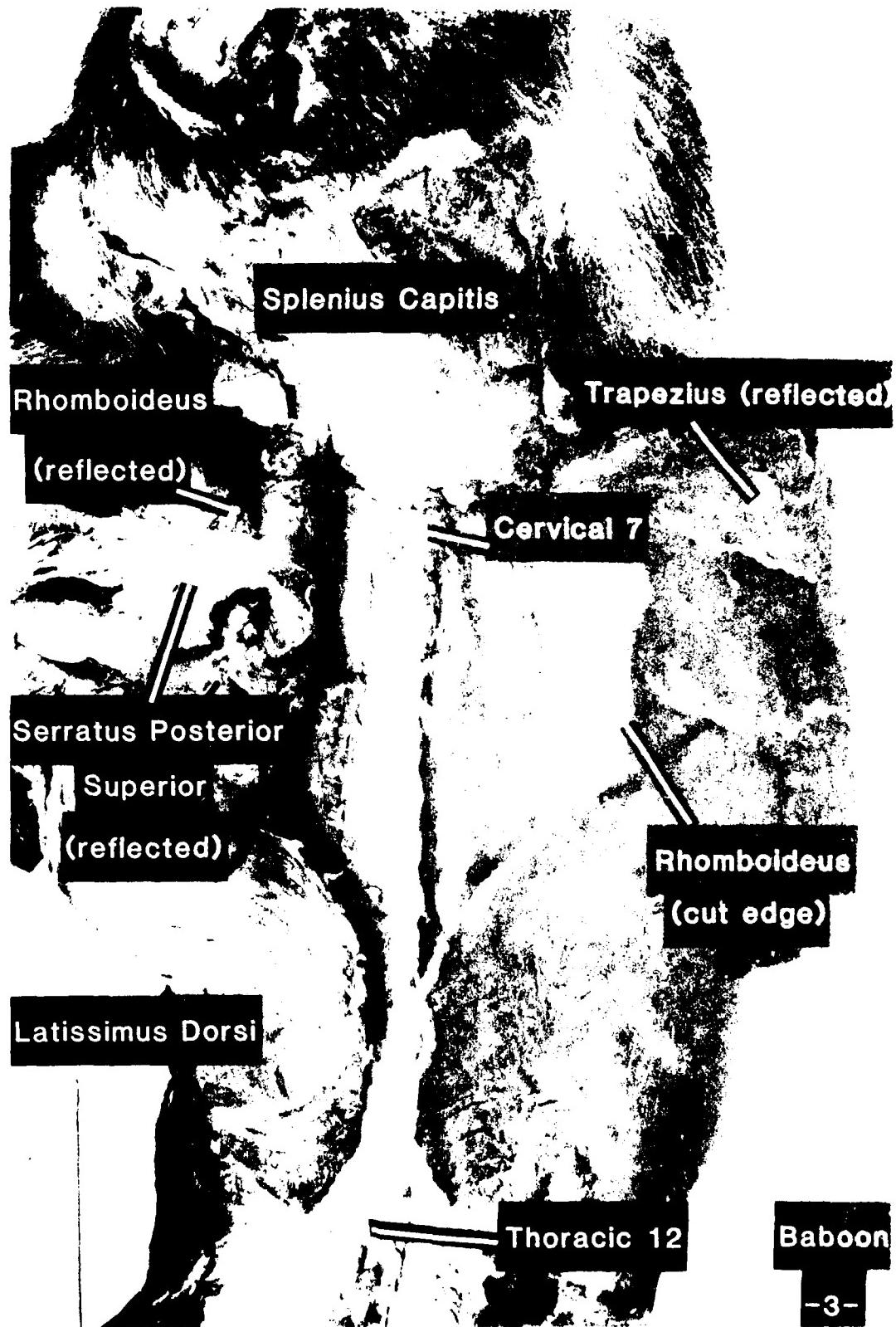
Semispinalis Cervicis
(reflected)

Spinous Process Cervical 7

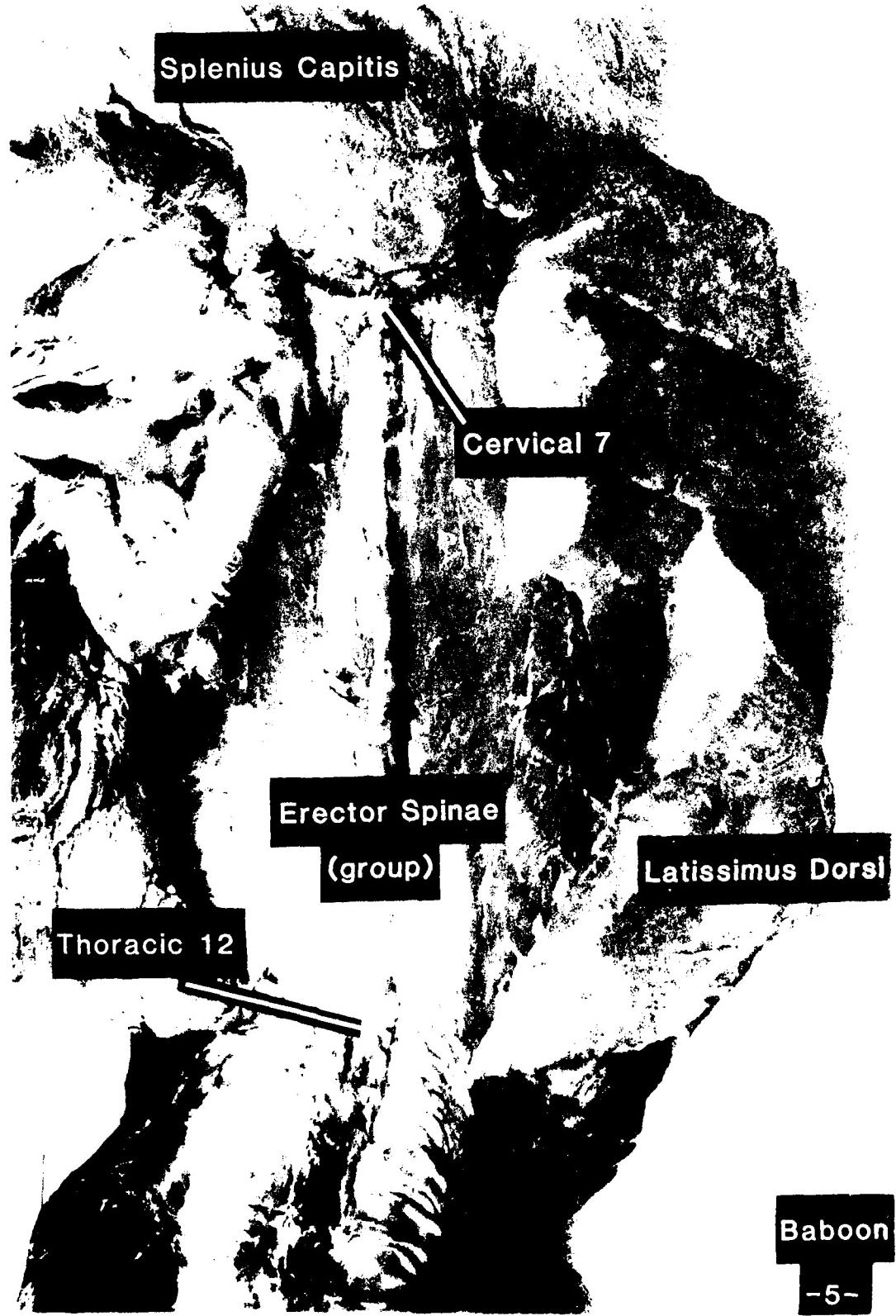
Intervertebral Muscular System

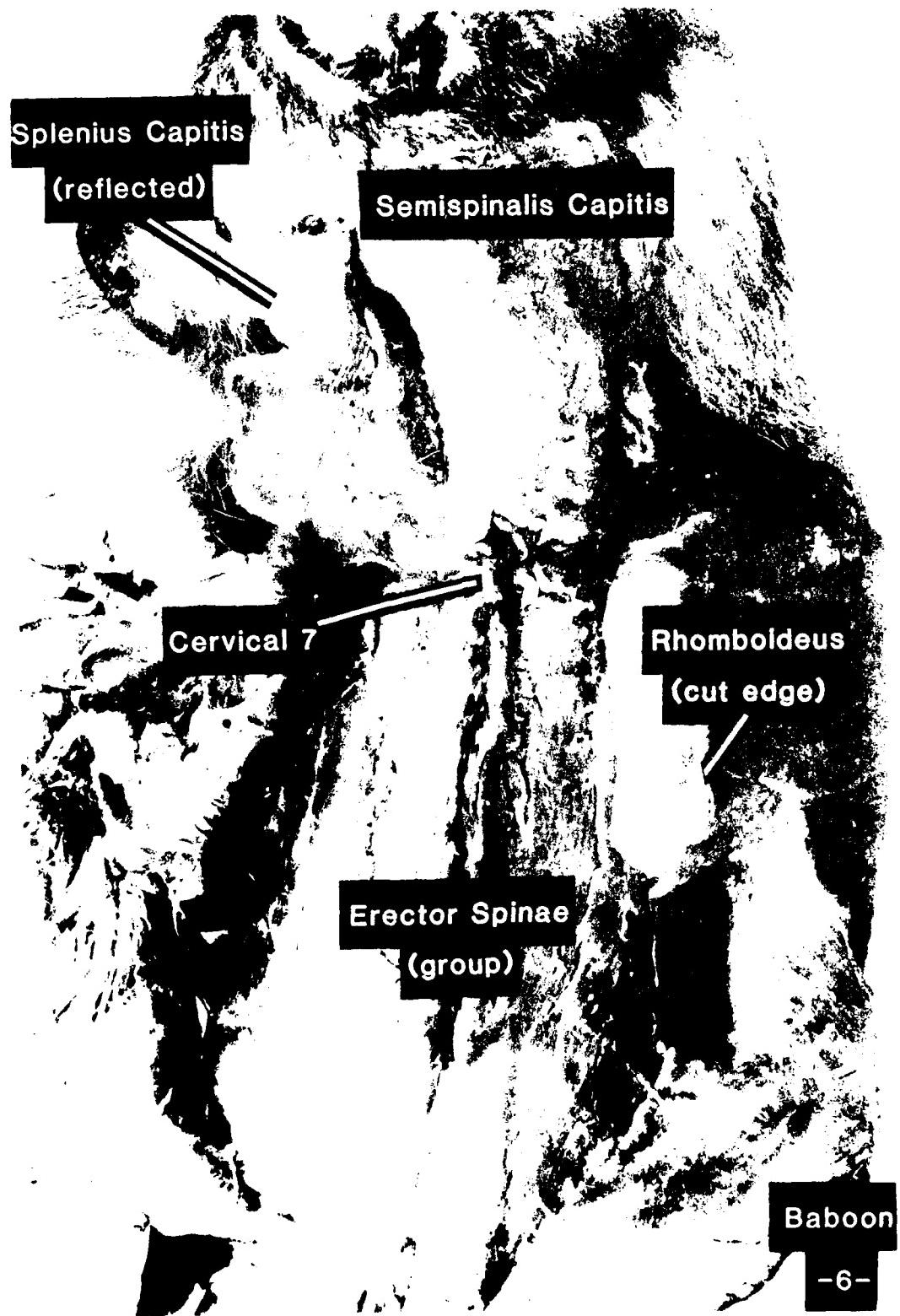


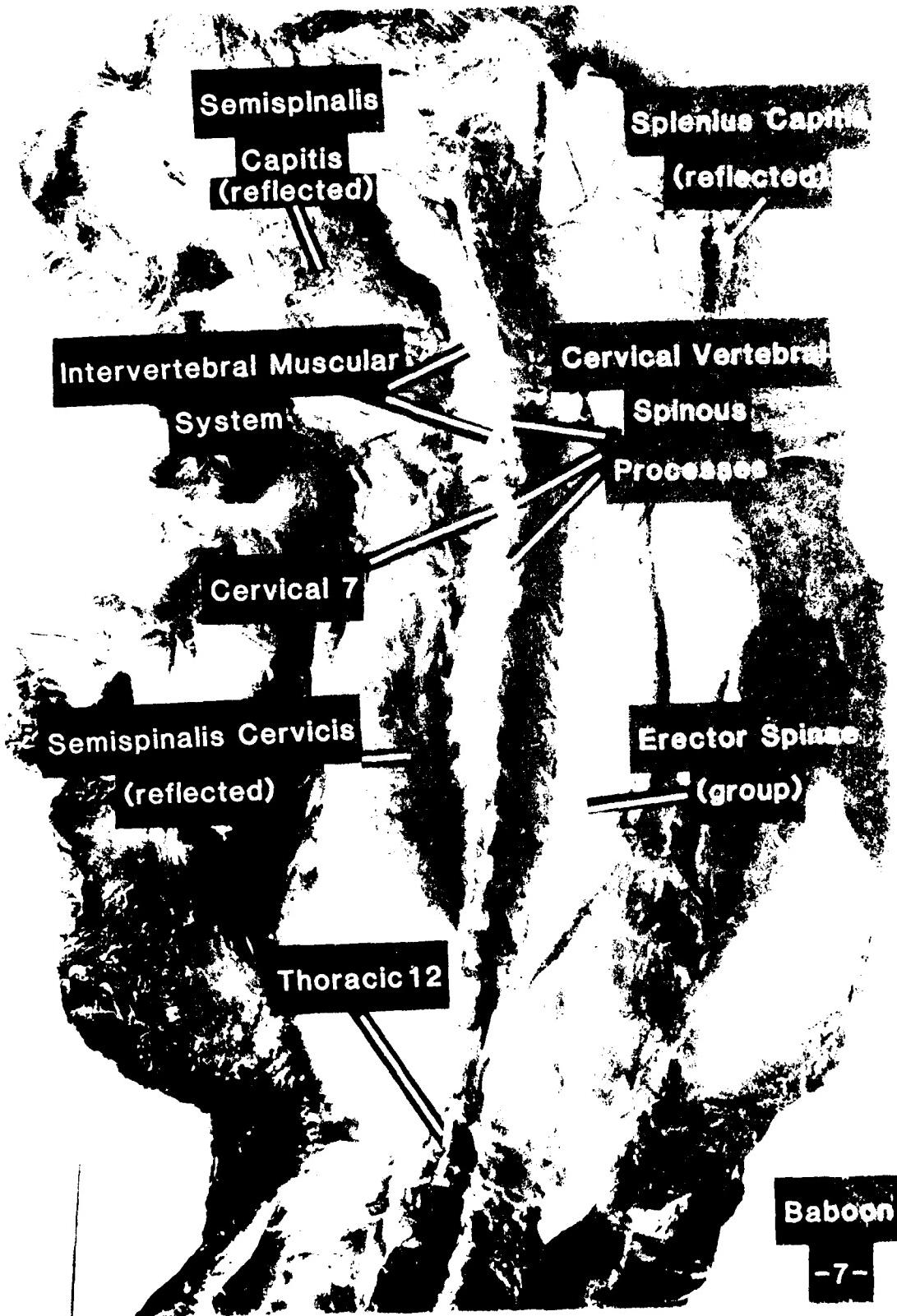


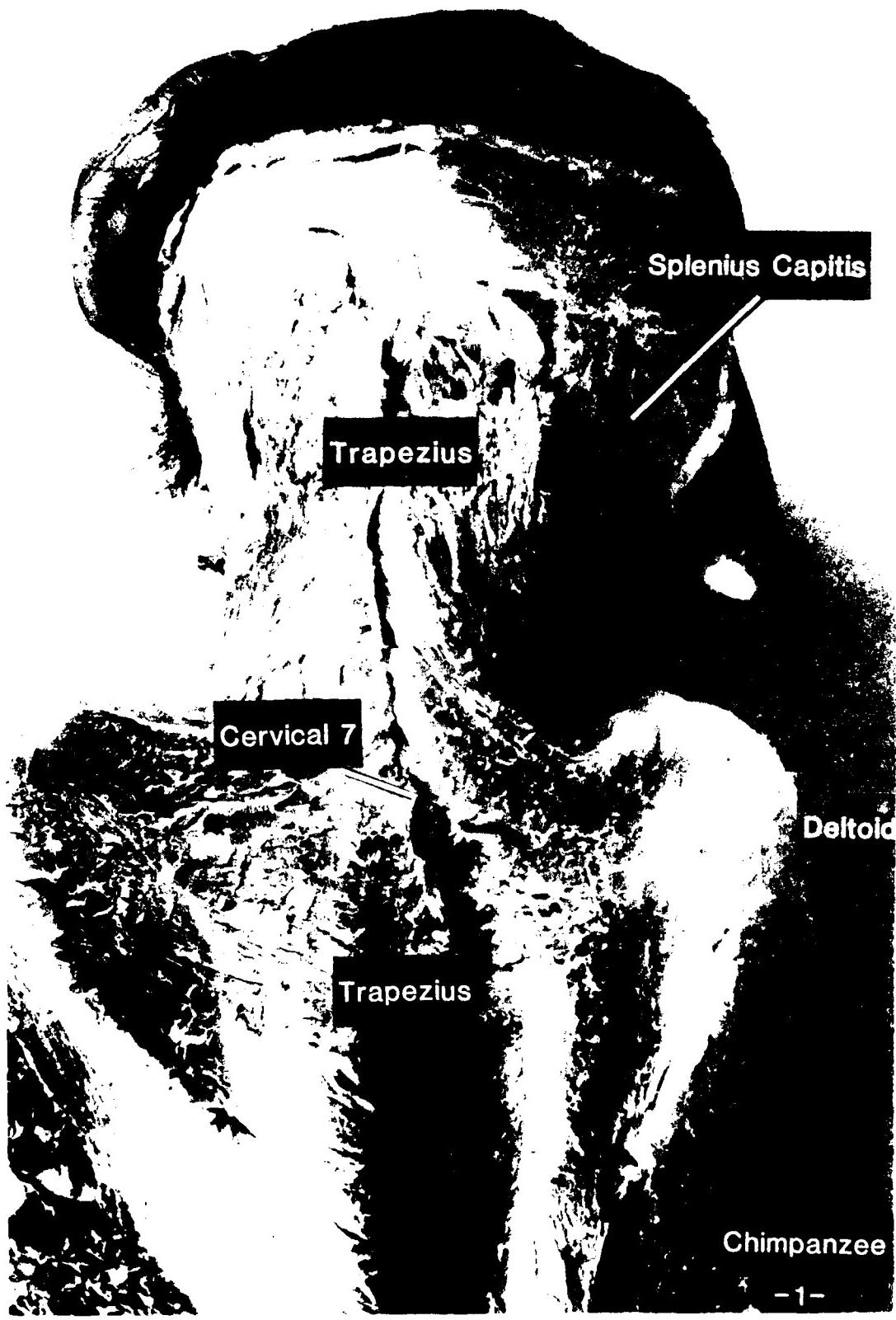


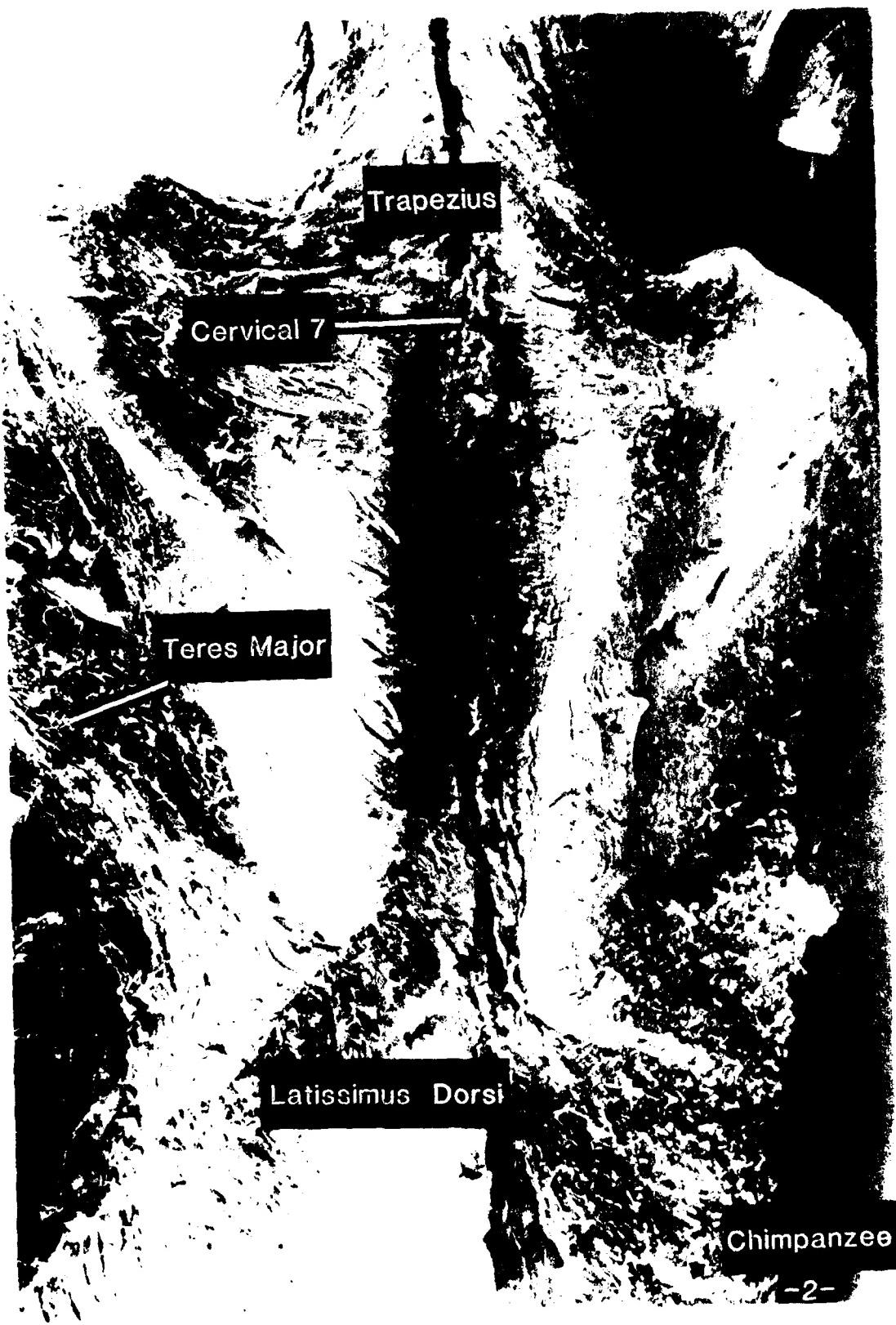








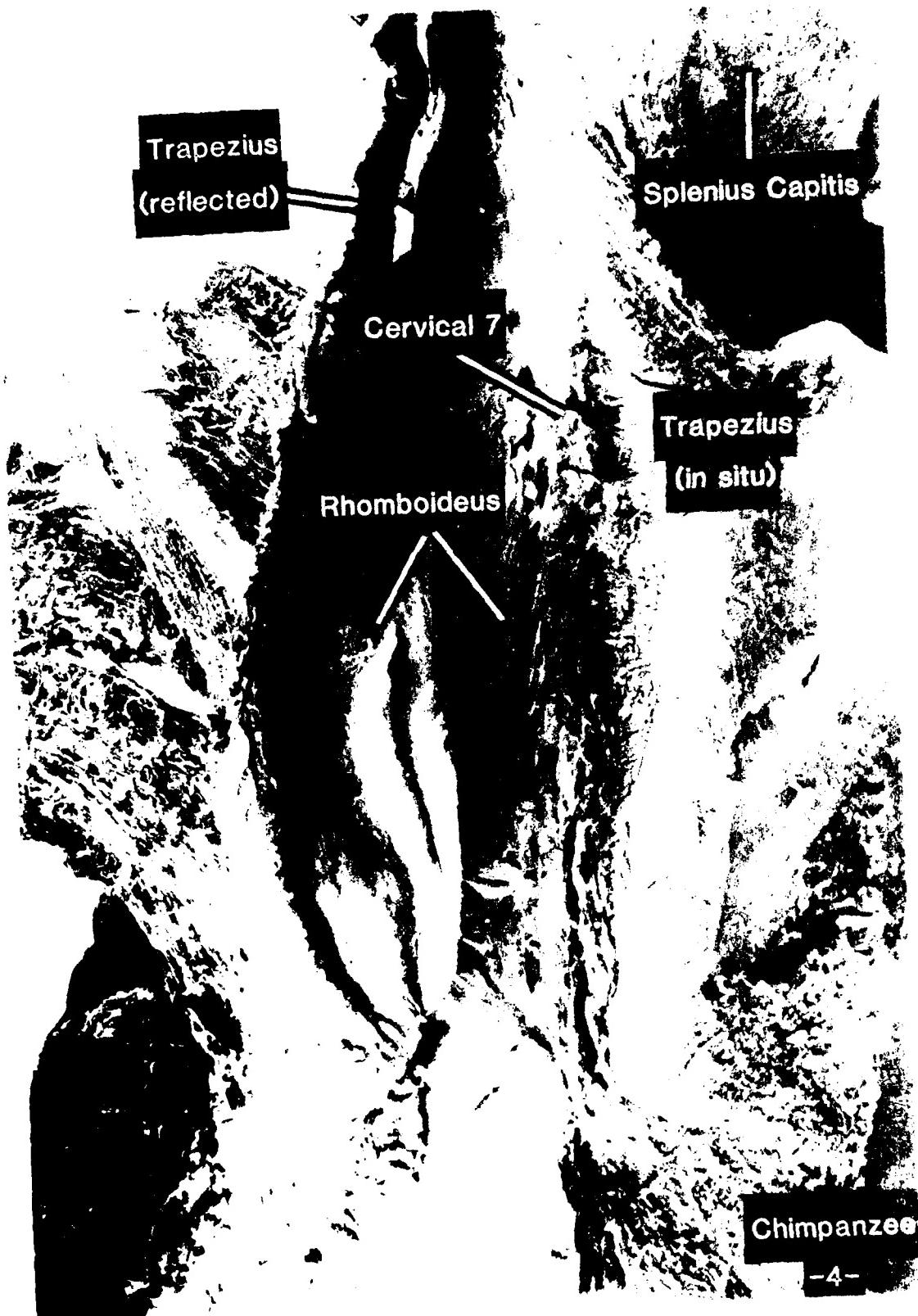


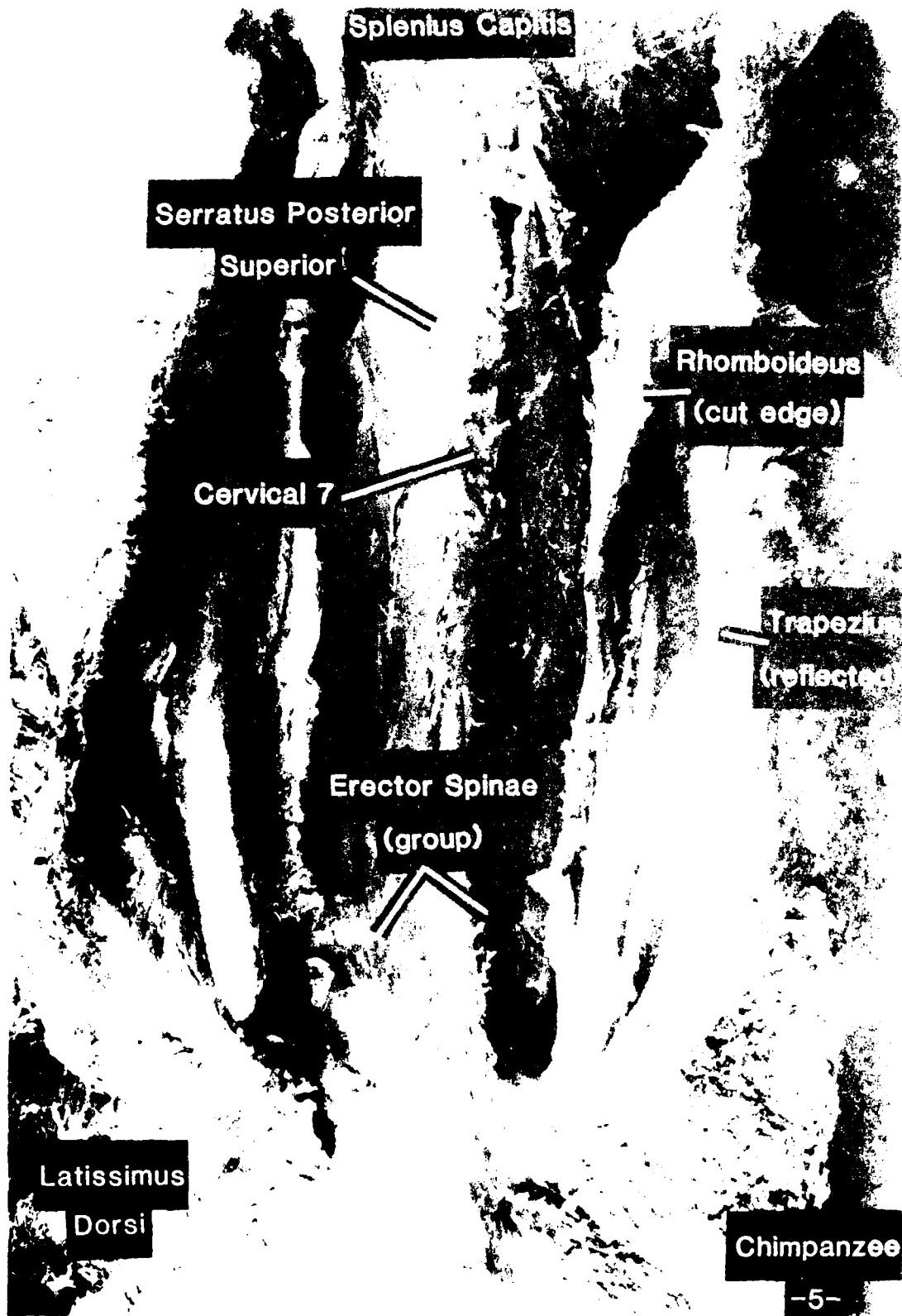


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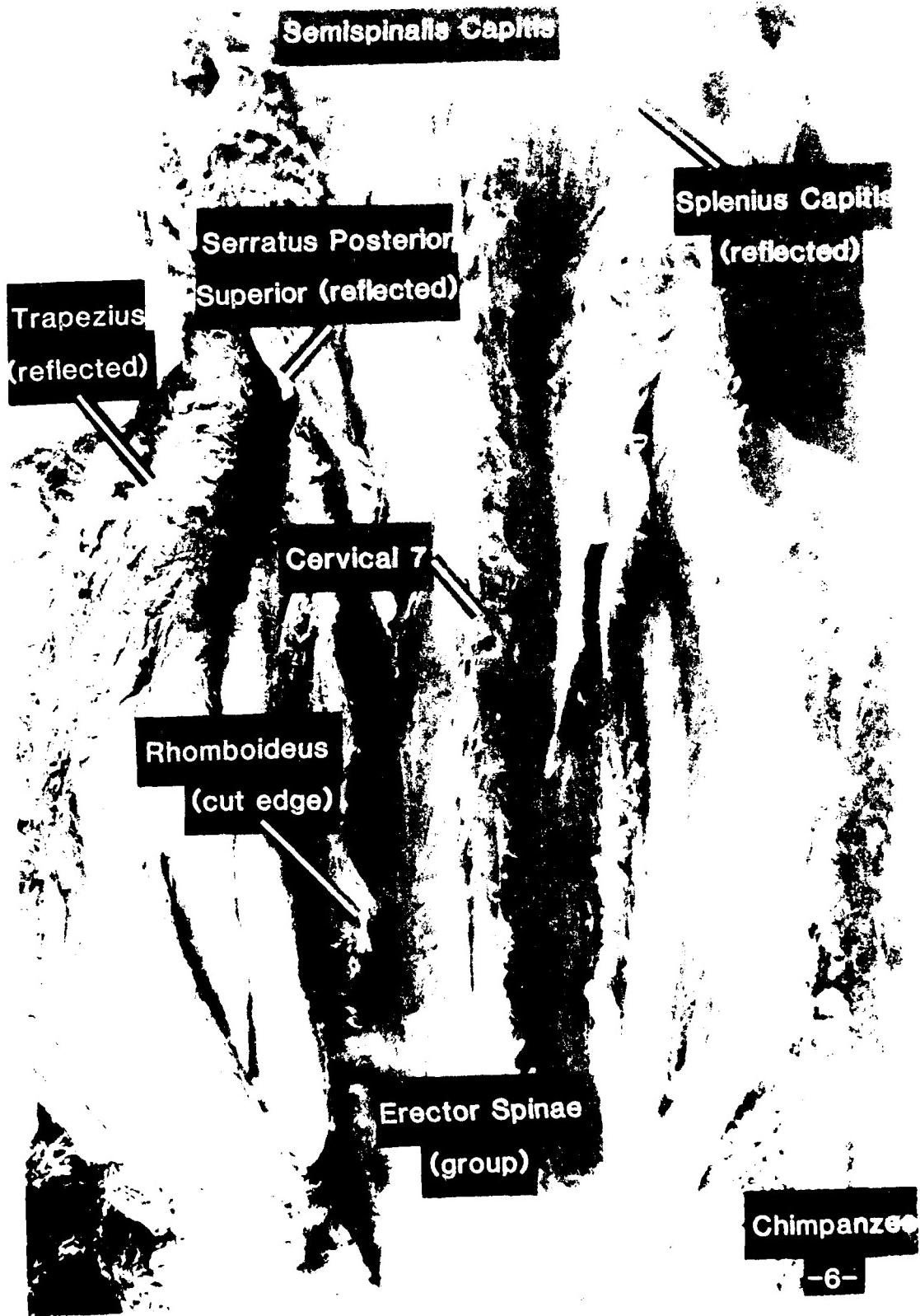


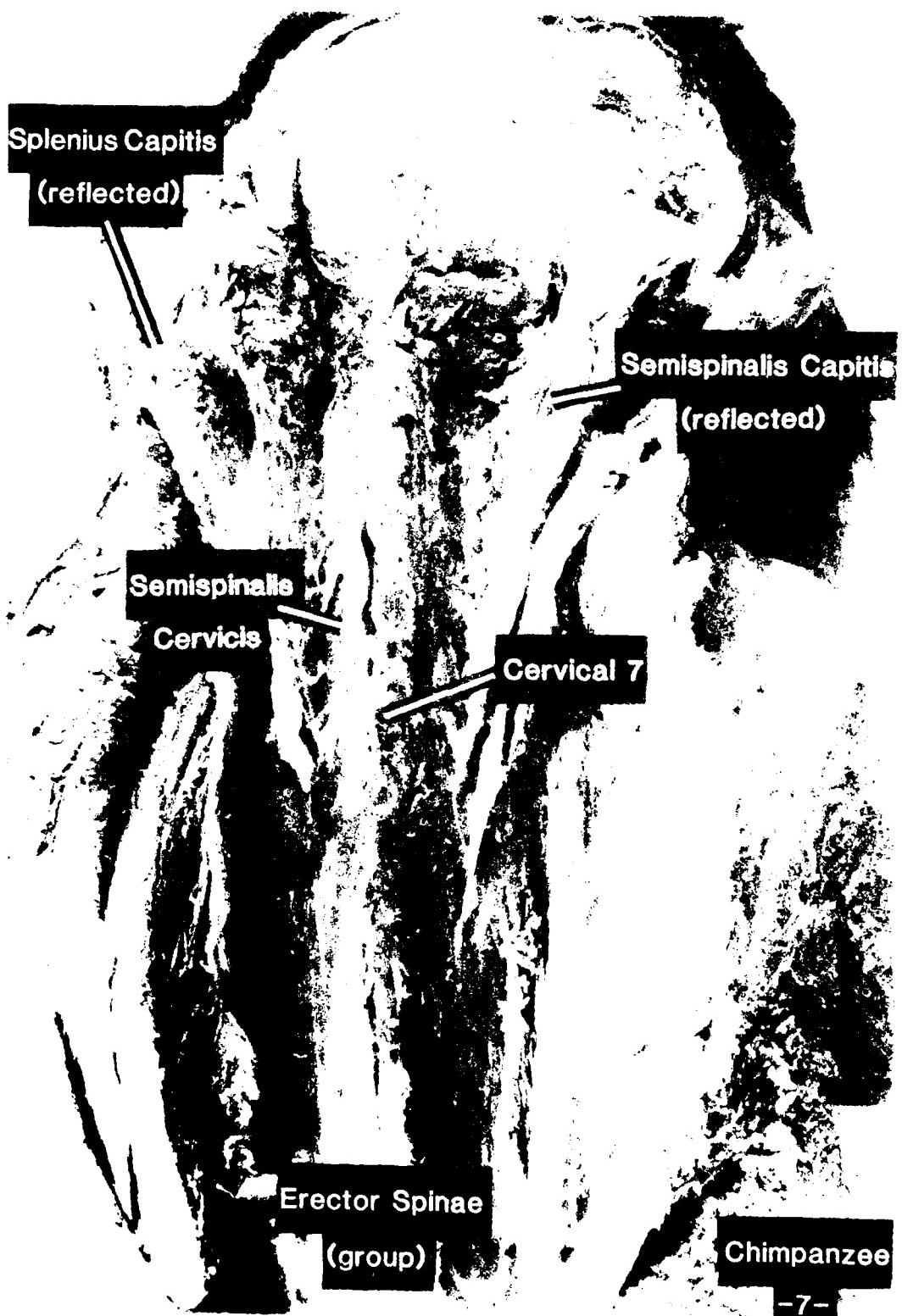
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-5-





Splenius Capitis
(reflected)

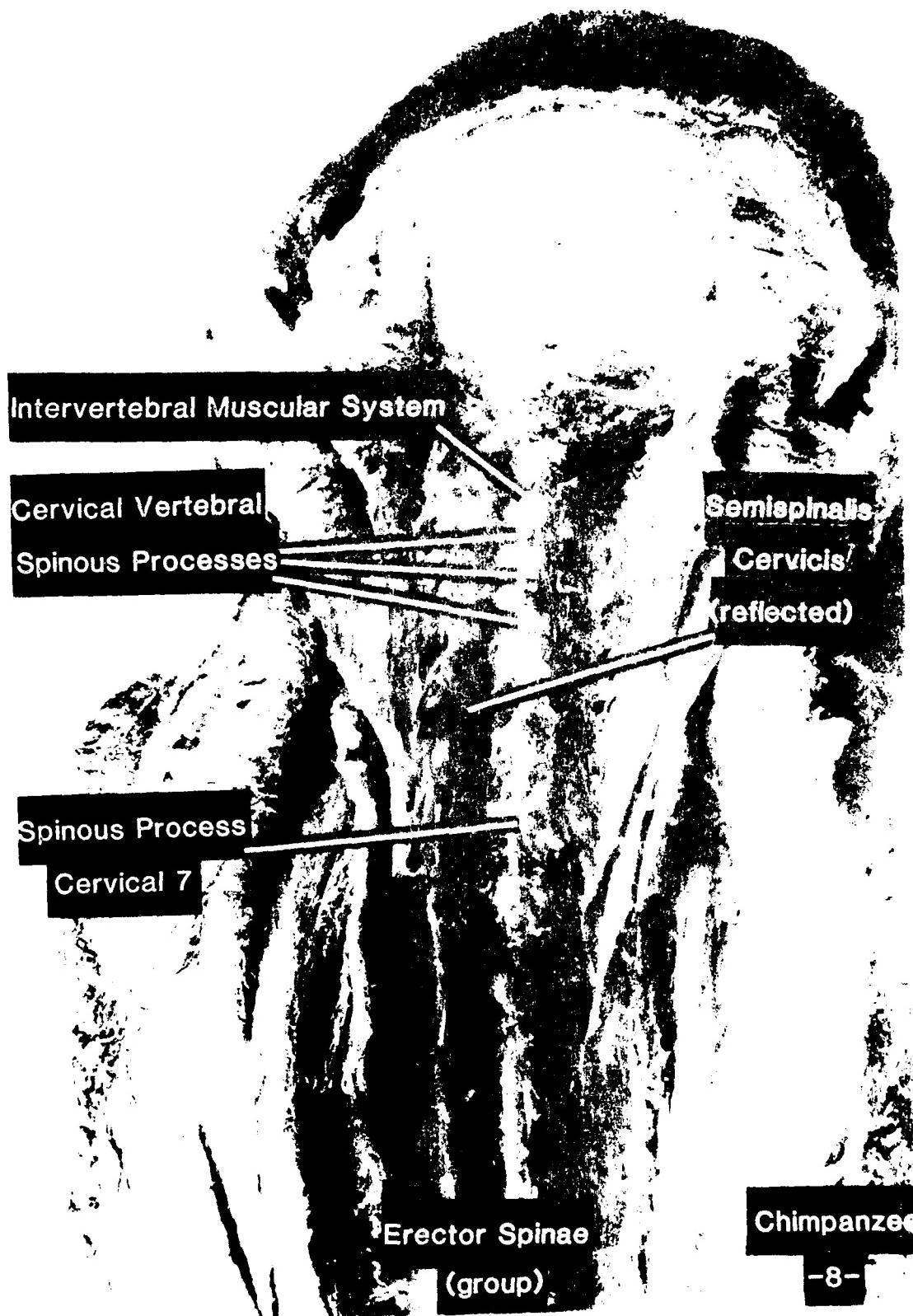
Semispinalis Capitis
(reflected)

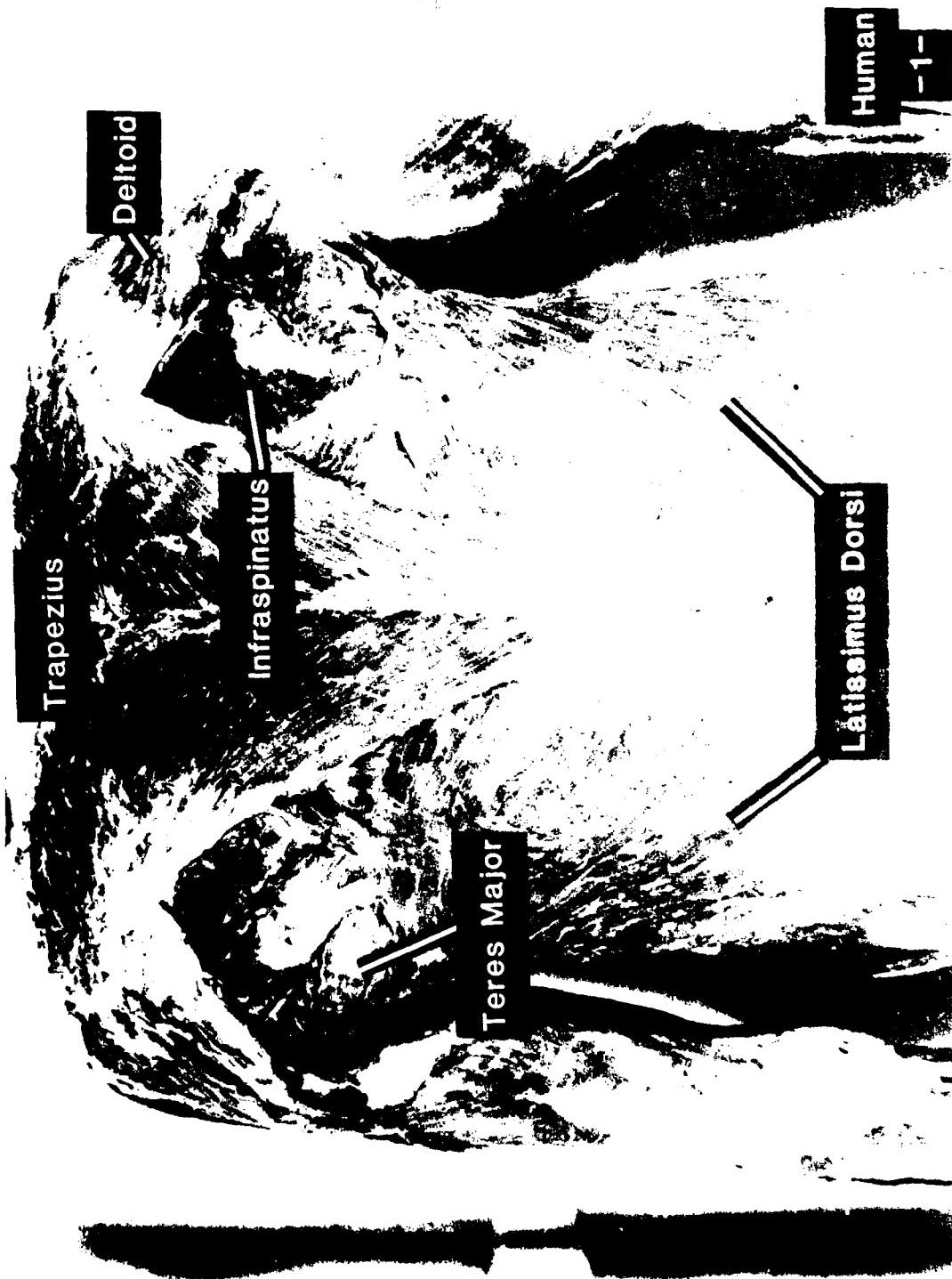
Semispinalis
Cervicis

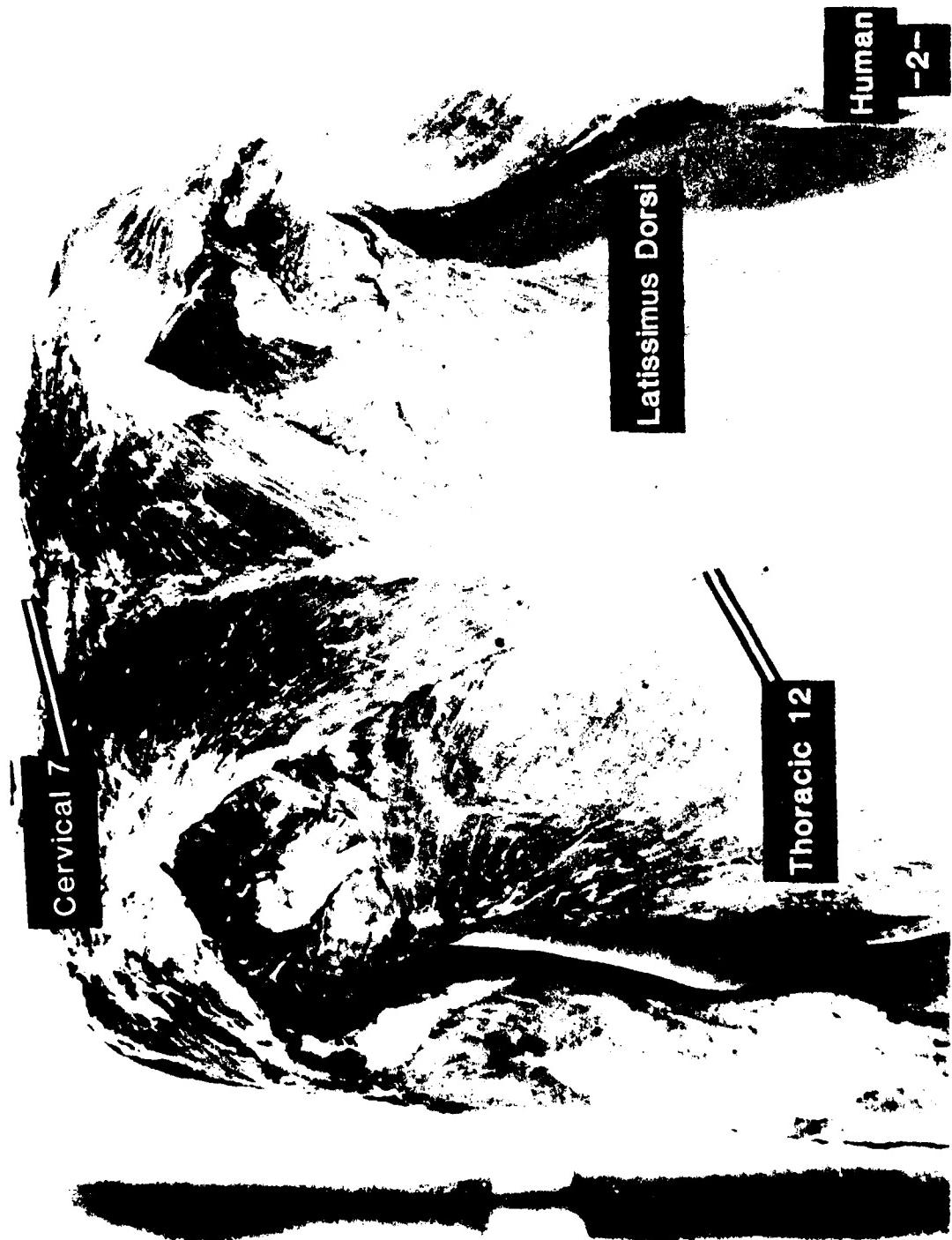
Cervical 7

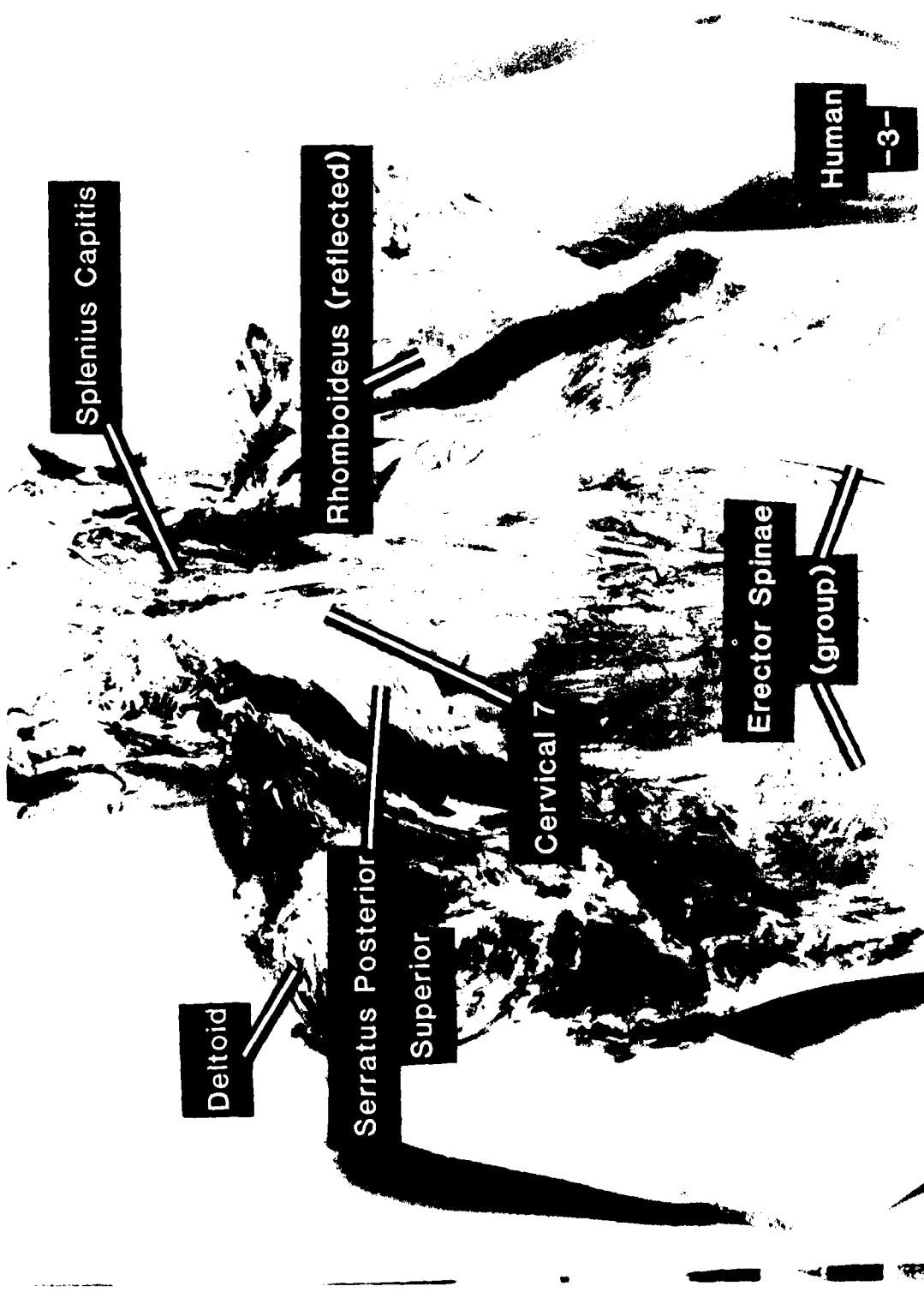
Erector Spinae
(group)

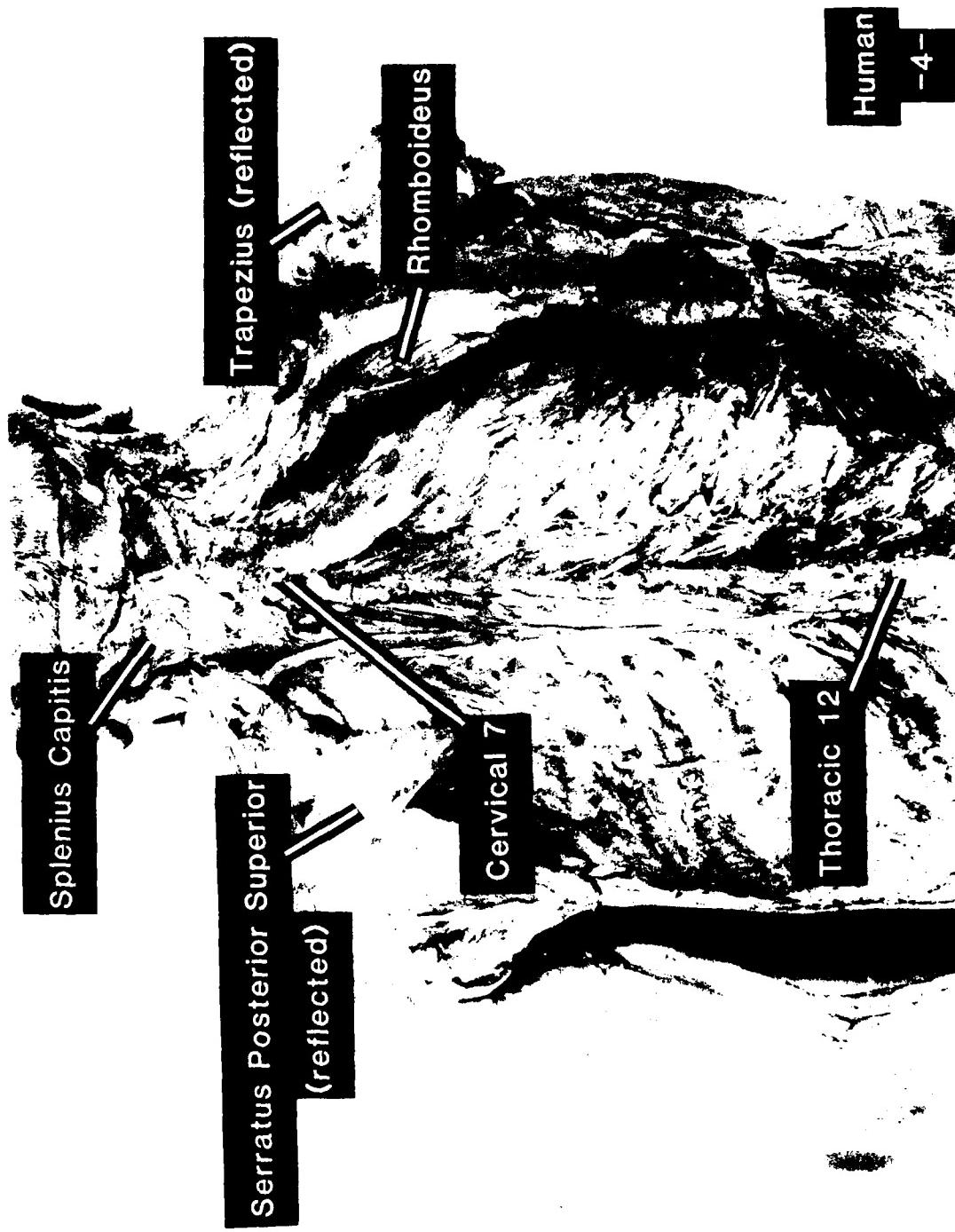
Chimpanzee

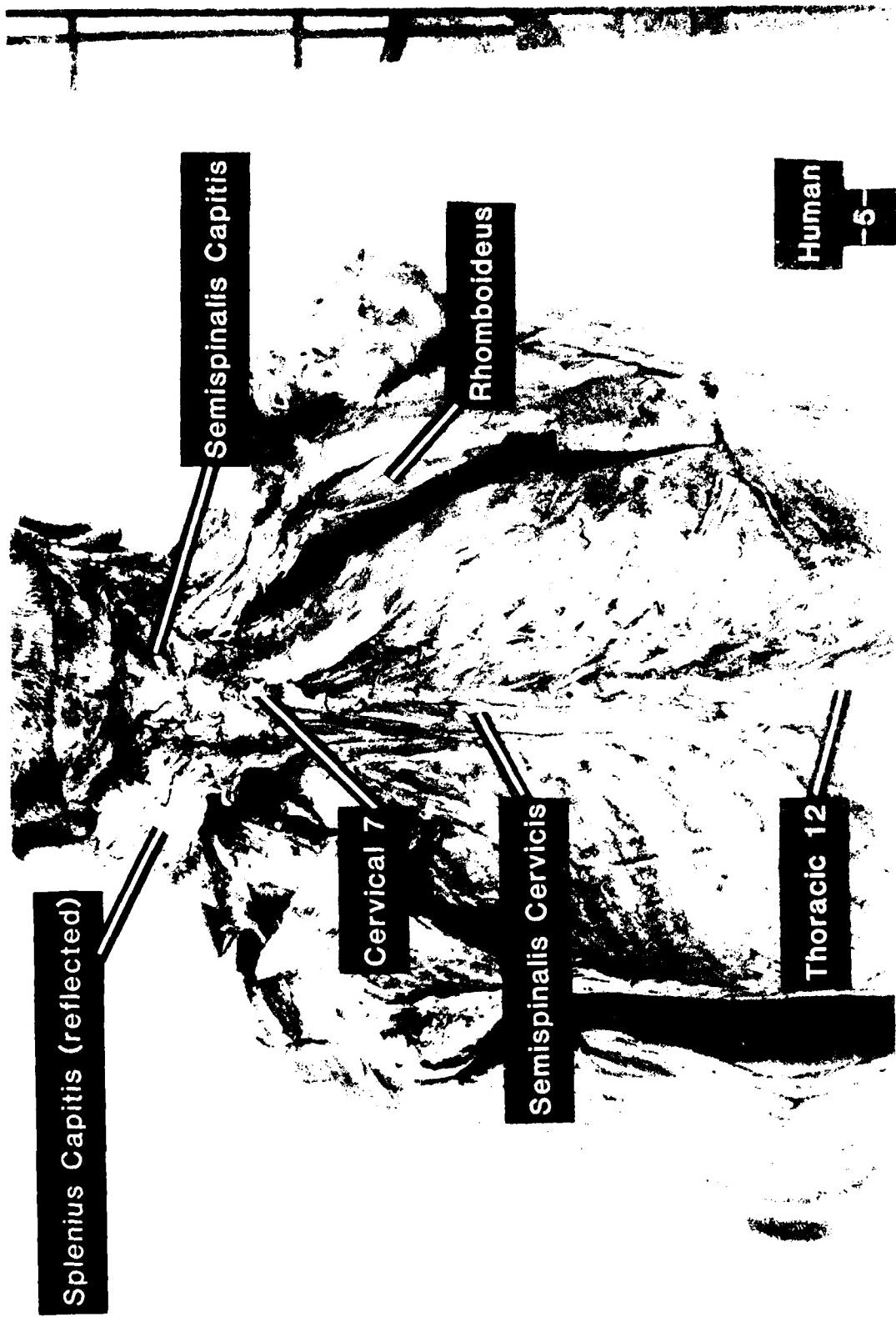






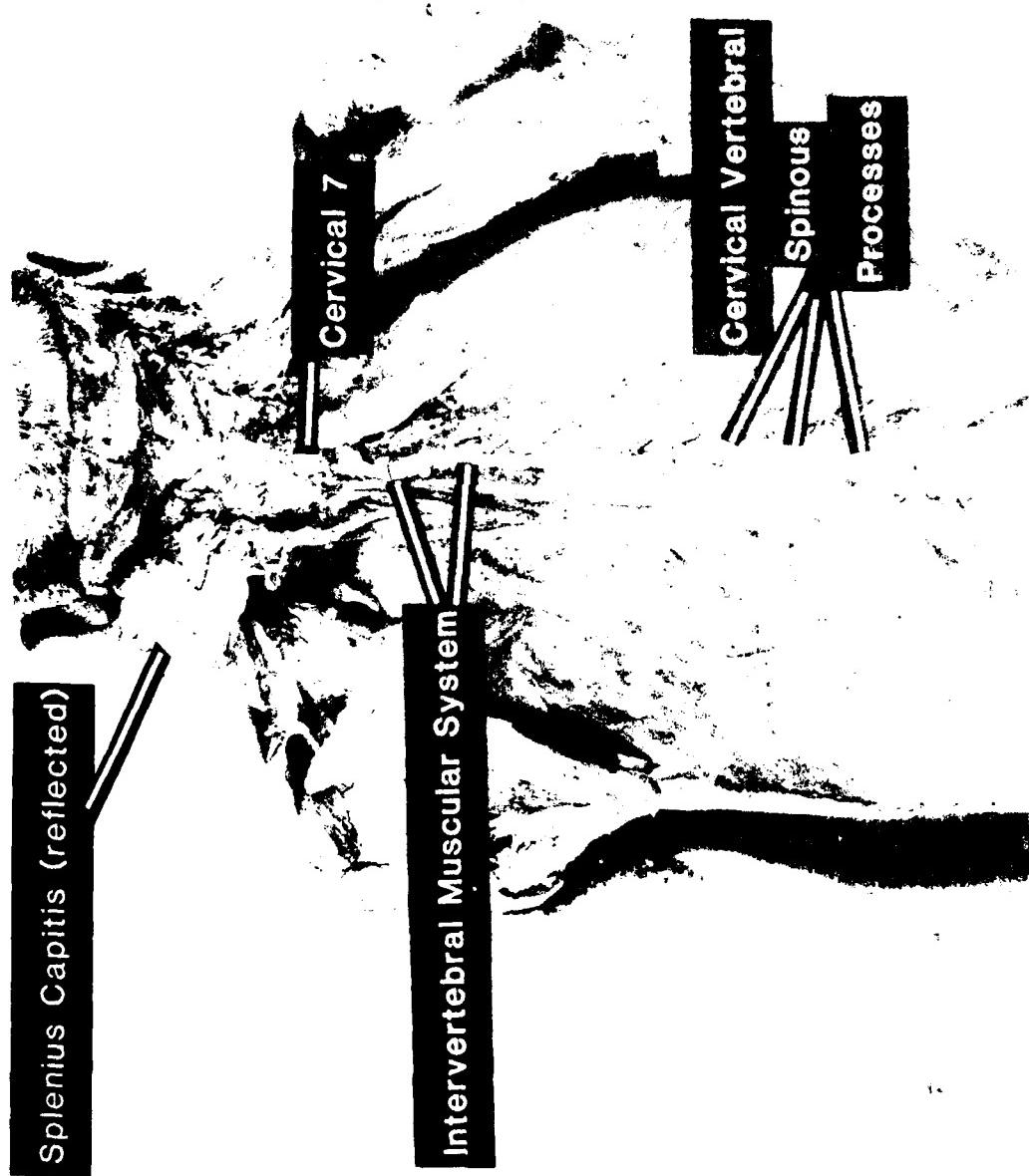






Human

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DISCUSSION AND SUMMARY

Routine anatomical methods were used to dissect and compare four primates. Prominent superficial muscles of the back were surveyed for comparative purposes while major attention was given to a survey of caudal paraspinal musculature.

For purposes of this discussion, the rhesus and the baboon are referred to by their locomotor description, that is, as quadruped; the chimpanzee is referred to as a brachiator; while the human specimen is a bipedal primate.

In the superficial musculature, differences were observed between the quadrupeds and the brachiator, while the human (biped) shared certain musculature characteristics with each. For the superficial musculature, the panniculus carnosus is extensive in the rhesus, less obvious in the baboon, and difficult to observe and variable in the chimpanzee and human. The trapezius muscle varied between specimens in the thoracic limit of its origin. It was thin and more delicate in appearance in the quadruped and human, while thick and strong appearing in the brachiator. The latissimus dorsi muscle was also thin and delicate in the quadrupeds and human, while thicker and stronger in the brachiator. The superior portions of the latissimus in the quadrupeds converged as a tendon to join the tendon of the teres major muscle. The remaining larger portions of the muscle formed a tendon that inserted individually on the humerus. The latissimus muscle in the brachiator and the human specimens had but a single band-like tendon that inserted upon the humerus. The deltoid muscle was relatively thin and small in the quadrupeds and human, while quite large and thick in the brachiator. The origin of the deltoid was similar in all four specimens; however, it inserted above the midpoint of the shaft of the humerus in the quadrupeds and below the midpoint of the humerus in the brachiator and human.

The teres major muscle was essentially similar in all four specimens (with the exception, as mentioned before, that the superior fibers of the latissimus dorsi muscle of the quadrupeds insert upon the humerus bone with the tendon of the teres major muscle). The serratus anterior muscle differed in size between specimens, this difference owing to the varying extent of the muscle origin.

For the deep musculature, the splenius muscle in the human was quite different than the same muscle found in the subhuman primates. The human splenius was more extensive, comprising two separate muscles, while the morphology and relationships of the splenius in the remaining specimens were essentially comparable. The rhomboides muscle was easily divisible into three separate portions in the rhesus; the baboon and the human specimens had a rhomboides muscle that could be separated into two major portions, while the rhomboides in the chimpanzee was a single sheet of muscle. Other than the separable or individual nature of the rhomboides, the muscle was essentially similar as per the origin, insertion and path of the fiber bundles.

The remaining muscles (serratus posterior superior, atlantoscapularis, erector spinae, transversospinalis, and intervertebrals) located deep in the back and associated directly with the vertebral column were found to be essentially similar with only slight variations being noticed.

In general, with the exception of the splenius muscle, the anatomical

variation was greater in the superficial musculature than in the deeper paraspinal muscles. The narrower, band-like muscles of the deep group were essentially comparable and consistent in our specimens. The human specimen shared certain superficial muscular characteristics with each of the other two locomotor groups; however, all four species had very similar deep paraspinal musculature.

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